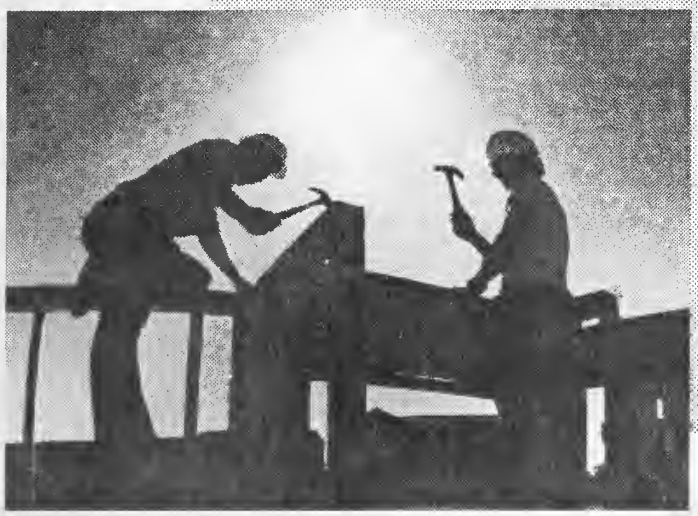
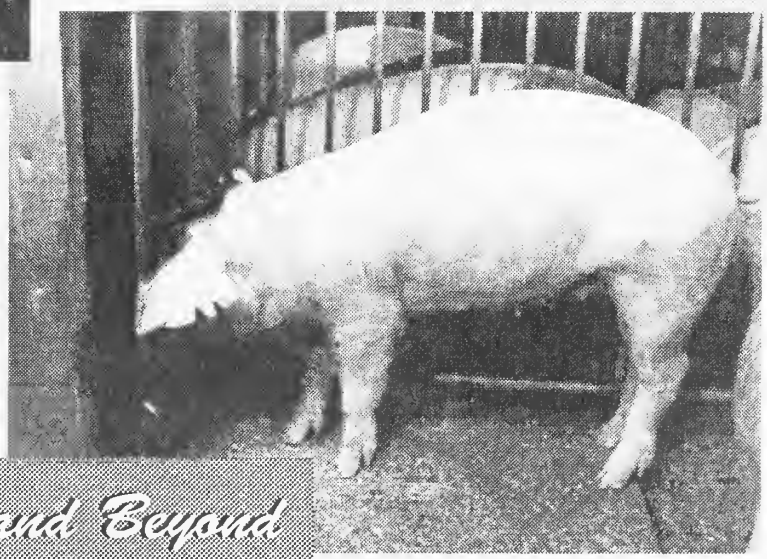
1995 Illinois Swine Research Reports

Department of Animal Sciences





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Contents

Swine Research Reports

Ideal Protein for Pigs

[1]The pig can be likened to a machine whose purpose is to convert poorly palatable plant-source foodstuffs to highly palatable and nutritious animal-source protein. Pig meat has a high protein quality and is rich in several important micronutrients, including zinc, iron and B-vitamins. An important goal in pig research is to make this machine as efficient as possible while at the same time minimizing its efflux waste products.

Protein is a costly item in pig diets, so maximizing the efficiency of protein/amino acid utilization is very important. How can one maximize lean meat production with the absolute minimum intake of amino acids? Clearly, diets containing amino acids at minimally required levels (for maximal lean growth) with minimal excesses, is a critically important factor. Using chemically defined diets containing amino acids as the sole source of dietary nitrogen has allowed us to suggest that, with a near perfect amino acid balance, a 30-lb pig is capable of converting 87% of its absorbed nitrogen above maintenance to carcass protein (Chung and Bake, 1992a). This does not mean, however, that each of the 23 amino acids found in dietary protein are utilized at 87% efficiency for protein accretion. Indeed, some amino acids are used more efficiently than others, and understanding the rationale for this "differential" efficiency is important in applying the concept of an ideal protein to practical pig production (Baker and Chung, 1992).

Ideal Protein

Theoretically, an ideal pattern of amino acids should exist for each physiological function, but clearly, the ideal pattern will be different for each function, i.e., maintenance, protein accretion, reproduction and lactation. For meat production, amino acid requirements can be separated into that required for protein accretion and that required for maintenance. Moughan (1989) and Fuller (1991) described maintenance as comprising 1) urinary excretion of unmodified amino acids, 2) use of amino acids as precursors for other essential body metabolites (eg., creatine from arginine and glycine; taurine and glutathione from cysteine, or indirectly from methionine; thyroxin, melanin and catecholamines from tyrosine, or indirectly from phenylalanine; serotonin from tryptophan; nucleic acids and choline from glycine or serine; carnitine from trimethyl lysine; nitrous oxide and polyamines from arginine; carnosine from histidine), 3) amino acids lost from integuments and epidermal structures, 4) obligatory oxidation of amino acids, and 5) amino acids lost from gastrointestinal epithelia (mucous, mucosal cells, digestive enzymes).

Of the total requirement for a given amino acid, protein accretion comprises well over 90% of the need for pigs weighing 20 lb, but as pigs approach slaughter weight, maintenance assumes

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[1]*Prepared by Dr. Dave Baker, Department of Animal Sciences, University of Illinois.*

greater prominence in the total requirement for an amino acid (Fuller et al., 1989; Black and Davies, 1991; Chung and Baker, 1992b, 1992c). Thus, while the ideal ratio of sulfur amino acids (SAA, i.e., methionine + cystine) to lysine is 60% for 20 lb pigs (Chung and Baker, 1992a) the ideal ratio for the maintenance component of that requirement is 136% (Fuller et al., 1989). Indeed, in every species where requirements for maintenance have been specifically studied, including studies with humans, the SAA requirement has exceeded the lysine requirement (Baker and Han, 1993). With an increasing contribution from maintenance as an animal grows toward slaughter weight, the ratio of SAA:lysine must increase, probably in a straight-line fashion, as a growing pig advances from 20 to 260 lb.

Based upon research with pigs in the weight category 20 to 40 lb, we have proposed a new ideal pattern of amino acids (Chung and Baker, 1992a; Baker and Chung, 1992). For the amino acids that are potentially limiting for pigs (i.e., lysine, sulfur amino acids, threonine and tryptophan) our ratios (to lysine) are not greatly different from those proposed most recently by Wang and Fuller (1990), although we feel Wang and Fuller's (1989) original estimate for tryptophan (18%) is more nearly correct while their revised estimate (Wang and Fuller, 1990) of 20% is too high. The principal difference between our "Illinois Ideal Protein" and that proposed by Wang and Fuller (1989, 1990) lies in levels of amino acids that are less likely to be limiting in practical-type diets. Thus, the Rowett group did not include estimates for arginine and histidine, and their levels of leucine, valine and aromatic amino acids are considerably higher than we feel are necessary.

Table 1. Ideal Pattern of Indispensable Amino Acids for Pigs in Three Separate Weight Categories[1]

	Ideal Patterns (% of lysine)		
Amino acid	10 to 45 lb	45 to 110 lb	110 to 250 lb
Lysine	100	100	100
Threonine	65	67	70
Tryptophan	17	18	19
Methionine	30	30	30
Cystine	30	32	35
Methionine + Cystine	60	62	65
Isoleucine	60	60	60
Valine	68	68	68
Leucine	100	100	100
Phenylalanine + Tyrosine	95	95	95
Arginine	42	36	30
Histidine	32	32	32

[a]From Baker and Chung (1990a) and Baker (1993; 1994); ratios are expressed on a true digestible basis.

Because the maintenance requirement for lysine is low relative to maintenance requirements for certain other amino acids (eg., threonine and cystine), ideal ratios of amino acids for young weanling pigs (10 to 40 lb) cannot be applied without adjustment to older market-type

projections of ideal ratios of amino acids for three separate

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or Finishing Pigs

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used are of PIC line 26 x Camborough 15 breeding. At a
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-rib fat depths of 1.1 in. (barrows) and 0.9 in. (gilts). Using
of 85% in a corn-soybean meal diet, we have translated our
irements to total lysine requirements (Table 2). Requirements
ne and tryptophan were estimated by multiplying ideal ratios
rement. The requirements for these amino acids are generally
ean meal diet is fed during early finishing and when a 12.5%
ng (Biehl, Hahn and Baker, 1994, unpublished data).
c line, we feel that stress-related decreases in voluntary feed
increased amino acid requirements expressed as a percentage

ERRATUM: In the last paragraph on page 5, the third sentence should read as follows: At a kill weight of 250 lb, these pigs typically have 10th rib loin-eye areas of 5.8 sq. **in.** (barrows) and **6.0** sq. in. (gilts) with 10th-rib fat depths of 1.1 in. (barrows) and 0.9 in. (gilts).

greater prominence in the total requirement for an amino acid (Fuller et al., 1989; Black and Davies, 1991; Chung and Baker, 1992b, 1992c). Thus, while the ideal ratio of sulfur amino acids (SAA, i.e., methionine + cystine) to lysine is 60% for 20 lb gain (Chung and Baker, 1992a) the ideal ratio for the maintenance compone (Fuller et al., 1989). Indeed, in every species where requirem specifically studied, including studies with humans, the SAA re lysine requirement (Baker and Han, 1993). With an increasing as an animal grows toward slaughter weight, the ratio of SAA: in a straight-line fashion, as a growing pig advances from 20 to

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Table 1. Ideal Pattern of Indispensable Amino in Three Separate Weight Categorie

	Ideal Patterns (	
Amino acid 10 to 45 lb	45 to 110 lb	110
Lysine	100	
Threonine	65	
Tryptophan	17	
Methionine	30	
Cystine	30	
Methionine + Cystine	60	
Isoleucine	60	
Valine	68	
Leucine	100	
Phenylalanine + Tyrosine	95	
Arginine	42	
Histidine	32	

[a]From Baker and Chung (1990a) and Baker (1993; 1994); ra digestible basis.

Because the maintenance requirement for lysine is low relative to maintenance requirements for certain other amino acids (eg., threonine and cystine), ideal ratios of amino acids for young weanling pigs (10 to 40 lb) cannot be applied without adjustment to older market-type pigs. Our calculations have led to projections of ideal ratios of amino acids for three separate weight categories of pigs (Table 1).

Use of Ideal Protein to Formulate Diets

Whether using total or digestible lysine requirement data, one can accurately formulate pig diets. Clearly, controversy surrounds the topic of digestibility, i.e., whether to use apparent, true or "real" digestibility values, or whether "bioavailability" (growth assay) values should be used for some ingredients like cottonseed meal. With corn-soybean meal diets, the question is not real important because true digestibility values for the key amino acids (lysine, threonine, tryptophan and SAA) are about the same. Thus, using either digestible lysine or total lysine as a base, results in similar ratios and therefore in similar predicted requirements.

What really confuses accurate requirement predictions for amino acids other than lysine is use of unrealistic requirement values for lysine. There has been a tendency for some to assume lysine requirement values for finishing pigs that are higher than they really are. Thus, with either cheap lysine or cheap soybean meal it is not uncommon for dietary levels of lysine to increase. If excess (or "safety factor") lysine levels are fed, one should ratio threonine, SAA and tryptophan to the "real" lysine requirement, not to the excess dietary lysine level, in calculating dietary ratios of threonine, SAA and tryptophan. If such ratios fall below 70, 65 and 19%, respectively, for finishing pigs (Table 1), then supplementation with one or more of these amino acids (or with more soybean meal) is necessary.

Realistic Lysine Requirements for Finishing Pigs

We have recently been working on digestible and total lysine requirements of finishing barrows and gilts during two growth periods, 110 to 200 lb and 200 to 250 lb (Hahn and Baker, 1994). The pigs we have used are of PIC line 26 x Camborough 15 breeding. At a kill weight of 250 lb, these pigs typically have 10th-rib loin-eye areas of 5.8 sq. cm. (barrows) and 18.5 sq. in. (gilts) with 10th-rib fat depths of 1.1 in. (barrows) and 0.9 in. (gilts). Using a determined lysine digestibility of 85% in a corn-soybean meal diet, we have translated our determined digestible lysine requirements to total lysine requirements (Table 2). Requirements for threonine methionine + cystine and tryptophan were estimated by multiplying ideal ratios (70, 65, 19%) x the lysine requirement. The requirements for these amino acids are generally met when a 14.5% CP corn-soybean meal diet is fed during early finishing and when a 12.5% CP diet is fed during late finishing (Biehl, Hahn and Baker, 1994, unpublished data). Moreover, within a given genetic line, we feel that stress-related decreases in voluntary feed intake probably do not result in increased amino acid requirements expressed as a percentage of the diet (or calories).

Table 2. University of Illinois Requirements (% of Diet) for Key Amino Acids in Finishing Pigs[1]

Amino acid	Ideal ratio	110 to 200 lb		200 to 250 lb	
		Barrow	Gilt	Barrow	Gilt
Lysine	100	0.68	0.75	0.58	0.61
Threonine	70	0.48	0.53	0.41	0.43
Met + Cys	65	0.44	0.49	0.38	0.40
Tryptophan	19	0.13	0.14	0.11	0.12

[1]For PIC pigs consuming corn-soybean meal diets. Requirements for digestible lysine (Hahn et al. 1995) were converted to total lysine requirements by assuming an apparent digestibility value for lysine of 85% in a corn-soybean meal diet. Requirements for the remaining amino acids were calculated by multiplying the lysine requirement value in each category by the ideal ratios listed for threonine, SAA, and tryptophan (Hahn and Baker, 1995).

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The Effect of Starter Feeding Program on Growth and Body Composition Changes from Weaning to Market Weight in Swine

Introduction[1,2]

In most production systems, pigs suffer a slow-down in growth rate immediately after weaning. Social, environmental and disease stressors are undoubtedly involved. Diet, clearly, can have a profound effect. The shift from sow's milk to a simple corn-soy (low-quality) diet requires major changes in the gastrointestinal tract. If the change to a simple diet is made abruptly, growth performance suffers. This post-weaning growth slump can be greatly reduced by using a series of high quality diets rich in very digestible milk and animal products.

What are the long term consequences of the post-weaning growth slump? Do pigs that grow slowly after weaning "catch-up" or are they permanently stunted? More importantly, are there consequences for body composition at slaughter? The scientific literature is not clear on these points. Le Dividich et al. (1980) found that muscle growth in postweaning piglets actually proceeds even during periods of weight loss as body fat is used to provide energy for protein growth. Campbell and Biden (1978) found that compensatory growth does, in fact occurs, after an early, nutritionally-induced growth, depression. The issue is of economic importance to swine producers and a practical question for those developing growth models..

Objectives

This project had three objectives:

1. To compare the growth performance, weaning to market, of pigs fed either low or high quality diets in the nursery phase (weaning at three weeks to approximately 45 lbs) and standard diets from 45 lbs to 230 lbs.

2. To measure the effects of nursery feeding treatments on carcass composition at slaughter.

3. To obtain measurements of carcass composition during growth in order to develop equations to predict lean growth based on nursery feeding program.

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[1]Prepared by Kenny Whang, Graduate Research Assistnat and Robert A. Easter, Professor of Swine Nutrition, Department of Animal Sciences, University of Illinois.

[2]Supported in part by a grant from the National Pork Producers Council in cooperation with the National Pork Board.

Procedures

All three objectives of the project were addressed in the first experiment conducted. In Exp. 1, 45 barrows and 45 gilts derived from mating Yorkshire x Duroc females to Hampshire boars, i.e., crossbred pigs, were used Experiment 2 was conducted to confirm the results of Exp. 1 and to determine if the results were genotype dependent. There were 46 barrows and 46 gilts of the crossbred genotype previously described along with 46 barrows and 46 gilts obtained by mating Camborough 15 sows to Line 405 boars (Pig Improvement Company, Franklin, KY). These are referred to as seedstock (SS) pigs. For each experiment the pigs were weaned at 21 days of age and were immediately alloted to treatment from outcome groups formed on the basis of gender, litter of origin and weight.

The same post-weaning feeding strategy was followed in each experiment. Pigs were offered either a three-phase feeding program (phase 1, week 1 postweaning; phase 2, weeks 2-3 postweaning, and phase 3, weeks 4-6 postweaning) using high-quality diets or a single phase program based on a simple corn-soybean meal diet. The second feeding strategy was followed for six weeks after weaning. The feeding strategies were designed to either maximize growth after weaning or to cause a significant postweaning growth slump. All pigs were fed the same diets during the growing and finishing periods with the exception that in Exp. 2, gilts were fed a diet with one percentage unit more crude protein than barrows. The compositions of the nursery diets are shown in table 1. Additional details unique to each experiment follow.

Experiment 1: Postweaning feeding strategy and gender were the two variables examined in this trial. Weekly weight gain and feed intake data were collected Pigs that exhibited poor performance, i.e., growth that was two standard deviations different from the pen average, were removed from the experiment. Three barrows and three gilts from each treatment, i.e., 12 pigs, were slaughtered at weaning, day 3, day 7, day 14, day 42, day 82, day 152 and at the termination of the experiment by electrical stunning followed by exsanguination. Heads were separated from the body and the head body and emptied viscera were each ground three times through a 1.6 cm die. A composite whole-body sample was then prepared and analyzed for dry matter, ash, protein and fat. In this way it was possible to examine the effect of post-weaning feeding strategy on growth and lean and fat growth to market weight. From this data, lean and fat growth equations were developed for each feeding strategy.

Experiment 2: Three variables, feeding strategy, gender and genotype, were studied. Weight gain and feed intake data were collected as in Exp. 1. To establish a more *practical* test situation, death was the only factor that resulted in removal of a pig from the experiment. Ten pigs from each treatment combination, i.e., two feeding strategies, two genders and two genotypes, were killed in a commercial plant, carcass data were collected and the NPPC (1991) formula was used to estimate lean body mass.

Data from both experiments were statistically analyzed using the GLM procedure of SAS(1985).

TABLE 1. Percentage Composition and Calculated Analysis of Experimental Diets for Six Weeks Postweaning in Exp. and Exp. 2

Ingredient	High-quality diet[a]			Low-quality diet[a]
	Phase 1	Phase 2	Phase 3	
Corn	29.07	60.23	58.28	67.92
Dehulled soybean meal	10.02	10.98	23.61	23.30
Dried skim milk	20.00	20.00	0.00	0.00
Dried whey	20.00	0.00	10.00	0.00
Lactose	10.00	0.00	0.00	0.00
Fish meal	0.00	2.00	4.00	5.00
Plasma protein (AP-820)	5.00	2.50	0.00	0.00
Soybean oil	4.00	2.00	1.50	1.00
Lysine-HCl	0.00	0.12	0.25	0.26
Dicalcium phosphate	0.79	0.86	0.90	1.04
Ground limestone	0.32	0.51	0.66	0.68
Illini vitamin premix[b]	0.20	0.20	0.20	0.20
Trace mineral salt[c]	0.35	0.35	0.35	0.35
ASP-250	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated crude protein, %	20.00	20.00	20.00	20.00
Calculated lysine, %	1.38	1.35	1.35	1.35
Calculated ME, Mcal/kg	3.48	3.40	3.31	3.31

[a] The low-quality diet was fed for six weeks post-weaning. The Phase 1, Phase 2 and Phase 3 periods were 0-7 days, 7-21 days and 21-42 days postweaning, respectively.

[b] Provided per pound of diet: 3,000 USP vitamin A, 300 USP vitamin D_3, 40 USP vitamin E, 2.0 mg vitamin K, .015 mg vitamin B_{12}, 4 mg riboflavin, 11 mg D-panthothenic acid, 15 mg niacin and 150 mg choline chloride.

[c] Supplied the following: 20.05 ppm Mg, 90.38 ppm Fe, 100.58 ppm Zn, 8.09 ppm Cu, .35 ppm I and .30 ppm Se.

Results:

Growth performance data for Exp. 1 are shown in figure 1. As expected, average daily gain during the nursery phase was greater ($P<.01$) when pigs were fed the three-phase sequence of diets in comparison to the single, less digestible diet. Also, fewer pigs became morbid on the high-quality diets than the low-quality diets. Growth rates did not differ during the growing period. Barrows exhibited compensatory or catch-up growth; gilts did not. The catch-up growth seen in barrows is likely a consequence of the tendency for barrows to have greater voluntary feed intake than gilts. In this experiment, average daily feed intake during the finishing period was 7.6 lbs/day for barrows and only 6.9 lbs/day for gilts.

Because pigs were slaughtered and body composition determined at various times during the course of the experiment, it was possible to examine the effect of post-weaning feeding strategy on body composition changes over time. The overall data were selected for presentation in table 2. Note that the chemically-determined protein, fat, water and ash gains are reported in this table. The chemical analysis of the ground, whole body, although costly, provides a more accurate measure of component growth than estimates based on carcass measurements.

TABLE 2 EFFECT OF STARTER FEEDING PROGRAM ON DAILY GROWTH OF BODY COMPONENTS (Exp. 1)

Body component gain	Barrows		Gilts	
	Three-phase	Single-phase	Three-phase	Single-phase
Protein, g/day	90.18[a]	93.67[a]	99.54[b]	99.63[b]
Fat, g/day	204.01[a]	187.39[bc]	164.53[cd]	144.09[d]
Water, g/d	334.89[a]	341.09	367.79[b]	365.24[b]
Ash, g/day	14.31	15.09	14.95	14.89

[a.b.c.d] Means with different superscripts are different ($P<.05$)

Barrows had less ($P<.05$) daily lean gain than gilts but more ($P<.05$) fat gain than gilts. Water retention reflected the association of water with lean tissue, that is, increased protein gain was accompanied by increased water gain. Of particular importance is the observation that postweaning feeding strategy did not influence body composition at slaugther. This allows the suggestion that pigs are, in fact, capable of compensatory protein growth.

Growth performance data for Exp. 2 are shown in figure 2. In Exp. 2 both crossbred barrows and gilts displayed catch-up growth. However, compensatory growth did not occur in the case of the SS-origin pigs. It is possible that the ability of a pig to recover from a nutritional insult

postweaning is related to voluntary feed intake. Average feed intake by the crossbred pigs was 6.5 lbs/day during the finishing phase in Exp. 2 while the SS-origin pigs ate an average of 6.2 lbs/day.

Experiment 2 was designed as a more practical study. Standard slaughter measurements were used in the NPPC (1991) equation to calculate lean body mass. The results (table 3) were similar to those achieved with Exp. 1. Starter feeding program did not affect lean body mass at termination within sex or genotype. Gilts were leaner than barrows and pigs of SS- origin were leaner than the crossbred animals.

TABLE 3. MAIN EFFECTS OF GENDER, GENOTYPE AND STARTER FEEDING PROGRAM ON PERCENT LEAN AT MARKET WEIGHT (Experiment 2)

Item	Comparison	Carcass lean, %	Probability
Gender	Barrows	48.22	
	Gilts	51.66	P<.001
Genotype	Crossbred	49.07	
	PIC	50.8	P<.05
Feeding strategy	High-quality, 3-phase	49.67	
	Low-quality, 1-phase	50.2	P=.47

The results of these two experiments suggest that pigs may have the ability to compensate for nutritionally depressed growth in the period immediately after weaning. This finding is consistent with the results of Campbell and Biden (1978). The work also suggests that the effect may be genotype dependent. Maximal growth during the starter period may not be absolutely essential, especially if the growth is achieved by maximizing fat deposition. In fact the consistent trend in these experiments for pigs reared under the three-phase starter strategy to be fatter at slaughter needs to be carefully examined in a large-scale experiment to determine if it is, in fact, real.

Implications

It would be unwise to conclude from these experiments that low-quality diets should routinely be fed to nursery pigs. Barrows and gilts appear to respond differently as do different genotypes. However, in production environments characterized by low disease stress and high feed intakes during finishing, it may be possible to achieve feed savings through the use of cheaper, simpler nursery diets.

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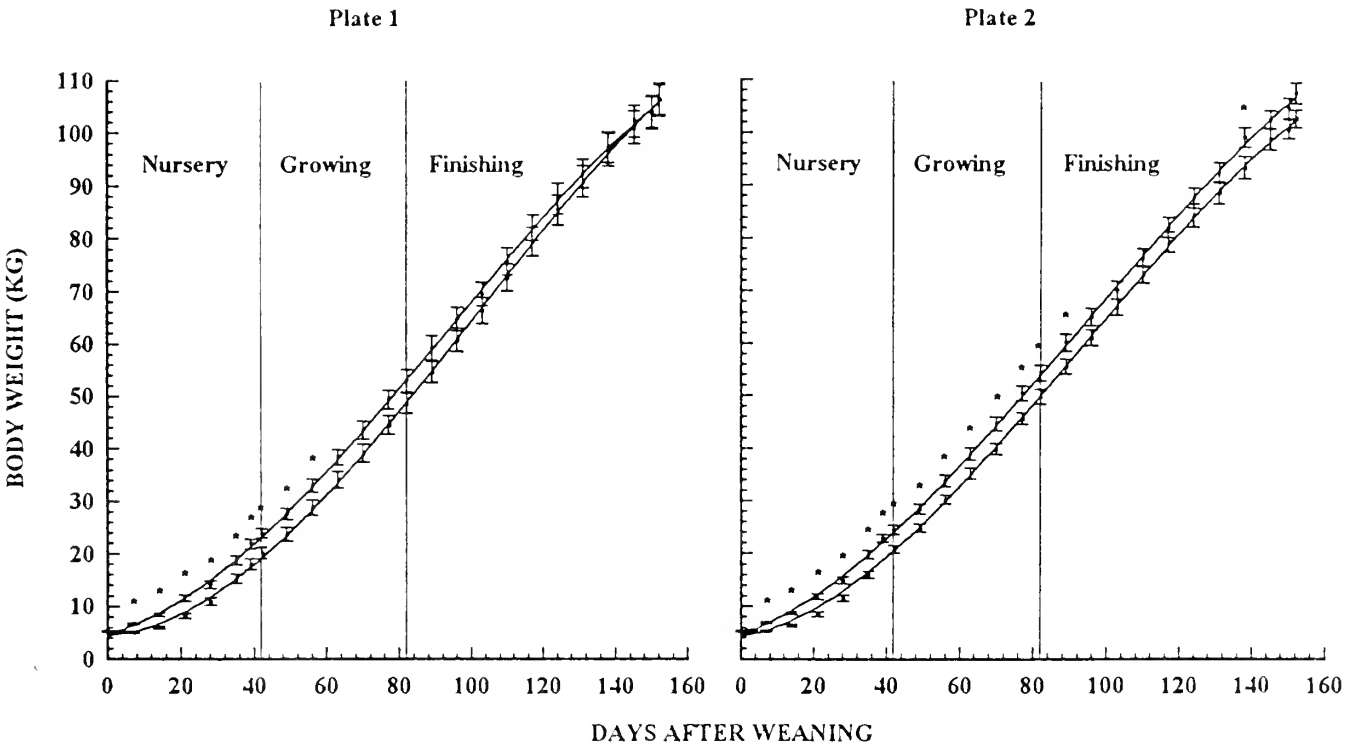

Figure 1. Growth response of crossbred barrows (plate 1) or gilts (plate 2) to either a three-phase, highly digestible, starter feeding program (○) or a simple-phase, less digestible, starter feeding program (□). Data points (Avg ± SE) with an asterisk (*) are significantly different ($P < .05$).

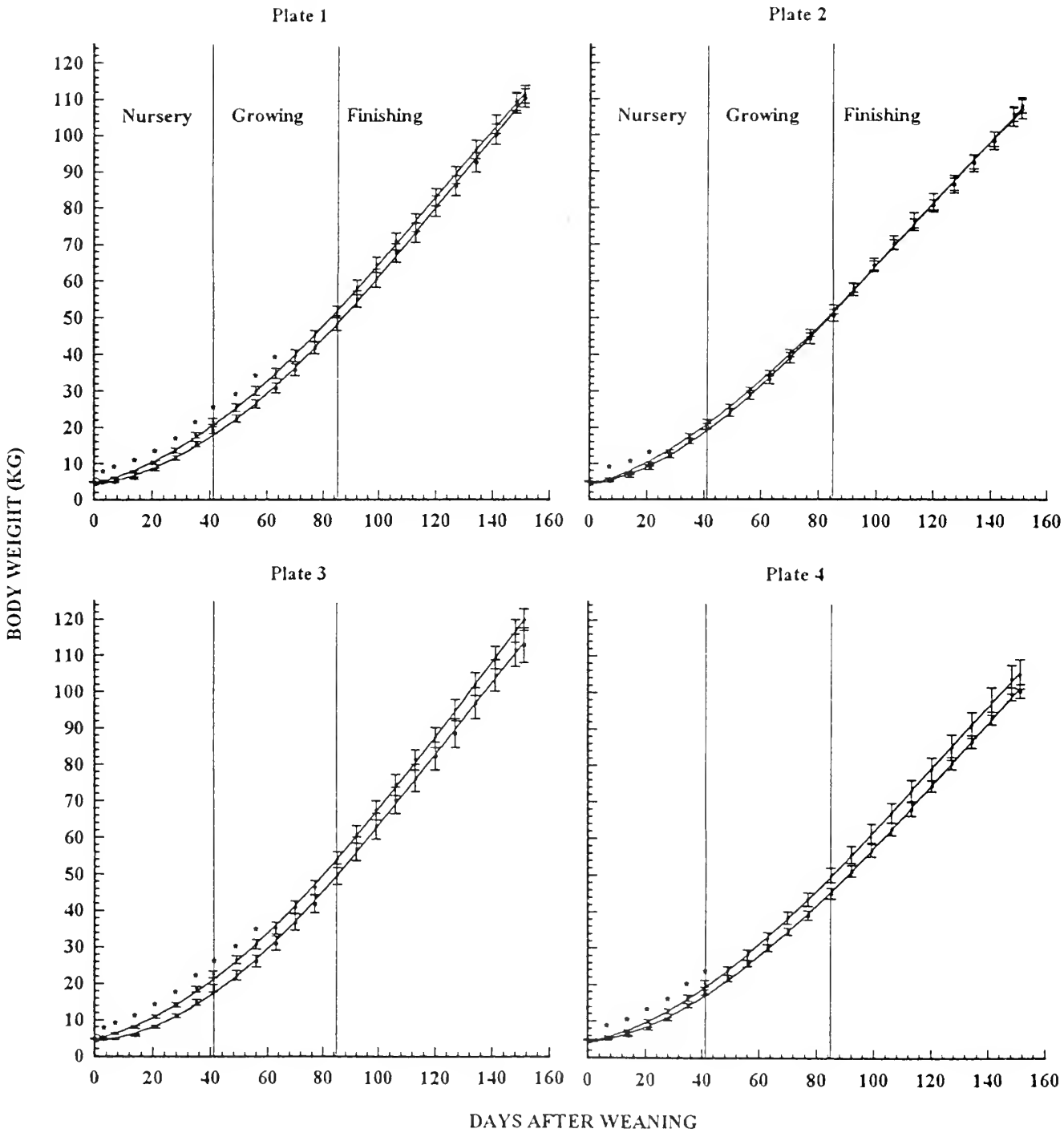

Figure 2. Growth response of crossbred barrows (plate 1) and gilts (plate 2) or PIC barrows (plate 3) and gilts (plate 4) to a three-phase, highly digestible, feeding program (○) or a single-phase, less digestible, starter feeding program (□). Data points (Avg ± SE) with an asterisk (*) are significantly different ($P < .05$).

Heavy Slaughter Weight in Pigs

Background[1]

There is continuous pressure from packers to take pigs to heavier slaughter weights in order to reduce operating costs in the slaughter house. More meat from fewer pigs is their goal. In the past, the swine industry has been unable to provide lean heavy pigs to the packers due to the increased fat levels in traditional genotypes. However, in recent years, the genetic potential of commercial swine has changed dramatically. Modern genotypes are leaner and grow faster. Consequently, a study was conducted to evaluate the performance of pigs taken to heavy slaughter weights in terms of growth, carcass composition, and meat quality.

Procedures

One hundred and sixty pigs from two genotypes were slaughtered at 100, 115, 130, 145 or 160 kg of live weight (220 to 352 pounds). Genotype A was a commercial breeding company hybrid and genotype B the result of a three-way cross of Yorkshire X Duroc dams bred to Hampshire sires. Equal number of barrows and gilts were used. They were allotted in groups of four animals and fed with a diet formulated to meet the NRC(1988) requirements. The weight at the start of the growth period was 60 kg.

Pigs were slaughtered at the Meat Science Laboratory using commercial procedures in the federally inspected facility. Live and hot carcass weights were recorded on the day of slaughter. Carcass composition and carcass quality was evaluated 24 h after slaughter.

Five trained technicians and graduate students evaluated sensory characteristics of the pork products. They evaluated tenderness, juiciness and off-flavor. Chemical analysis on a sample of loin was performed.

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[1]*Prepared by F. Cisneros, Dr.M.Ellis, Dr. F.K.McKeith, J.McKaw and R.Fernando, Department of Animal Sciences, University of Illinois.*

Results.

The most important results were :

1.- Pigs of genotype A ate more, and grew faster than genotype B; however, feed efficiency was similar for the two genotypes.

2.-For each kg over 100 kg of slaughter weight, an additional 1.19 days was required to reach slaughter weight. Changes in growth rate, feed intake and feed efficiency with slaughter weight were relatively small.

3.-Dressing percentage increased by 0.5 percentage units per 10 kg of slaughter weight. However, the percentage carcass lean content (trimmed and boneless ham + loin + Boston butt + picnic) was slightly reduced with heavier slaughter weights (0.32% for each 10 kg over 100 kg).

4.- Lean content of the carcass in absolute terms (kg) increased with heavier slaughter weights (ie. weight of lean cuts was 28 kg and 45 kg for 100 and 160 kg slaughter weights respectively).

5.- No important changes in meat quality were detected. However, fat content of the meat was increased and moisture decreased with heavier slaughter weights without compromising quality.

6.- There was no influence of slaughter weight on the curing yields of ham or belly.

Implication

In conclusion, lean genotypes with high lean growth potential can be taken to heavier weights without significantly compromising performance or carcass value.

Effect of Betaine in Finishing Pigs

Currently, betaine is being recommended as an agent to reduce fatness in swine. However, the use of betaine as an ingredient in the diets of farmed species is not a new concept. Betaine was introduced to the feed industry in the middle of this century as a replacement for methionine and choline in poultry diets. In 1990, a paper published by Saunderson and MacKinlay indicated that dietary supplementation of betaine reduced the fat composition in chick carcasses. This paper stimulated interest in using betaine in animal feeds as a lipotropic compound.

Betaine, otherwise known as trimethylglycine, is a naturally occuring compound that is present in all living organisms in variable quantities. Sugar beet molasses, cottonseed, and wheat germ have relatively high levels of betaine. The primary feed grade form of betaine is anhydrous betaine which is a 97 % pure, crystalline product that has a light brownish color.

The relationships of choline, methionine, and betaine is important in nutrition. All three compounds share the common function of supplying labile methyl groups, which are needed for various functions in the body. However, both choline and methionine have essential functions which have been termed irreplacable since they cannot be replaced by either of the other nutrients. These functions include protein synthesis and membrane formation for choline and methionine, respectively. Betaine can replace choline and/or methionine once the essential requirement for these nutrients has been met.

Two studies from Austraulia showed that dietary betaine supplementation (.125%) reduced the backfat of finishing gilts by 12-14%, however, no response to betaine was found when it was fed to finishing boars. The researchers suggested that betaine only reduced the backfat in gilts because it only affected the fatter pigs. It is important to point out that the pigs used in these experiments were very lean in comparison to typical U.S. genotypes and also that the ingredients used are not commonly utilized in U.S. swine production. Several other studies at various research stations around the U. S. have reported variable results to betaine supplementation, some positive and some negative.

A trial was conducted at the University of Ilinois to evaluate the effects of betaine supplementation (.125%) on growth performance and carcass characteristics of finishing swine. Mixed sex crossbred pigs weighing approximately 160 pounds were fed betaine for the 42 days prior to slaughter at an approximate weight of 253 pounds. The diets were formulated to contain 15 and 16 % crude protein for barrows and gilts, respectively . Diets were adequate in both choline and methionine and were fed free choice throughout the study.

The results from the U of I trial indicated that betaine supplementation of a corn-soybean meal diet, adequate in both choline and methionine, did not affect growth performance or carcass characteristics of finishing pigs. There is currently no explanation as to why betaine decreased the backfat of finishing pigs is other studies.

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The Nutritional Value of High–Oil Corn

[1]

Corn is the major grain crop in livestock feed in the United States, and it is generally the major energy containing feedstuff in swine feed. The major energy contributing nutrient in corn is starch. The protein fraction makes up only 8.5% and the fat content only 3.7%. Hence, corn is usually not considered an oilseed crop.

Through genetic selection over many years, certain varieties of corn with a higher content of oil have been bred. The efforts in this area started nearly 100 years ago, when a classical breeding experiment at the University of Illinois was initiated by Dr. Hopkins. By selecting for oil content over 70 generations it was possible to increase the oil content to a level of 17 %, and after 82 generations, the oil content was 19%. Since these lines were only selected for their oil content, the yield was only about 30 % of the yield of commercial hybrids, - for this reason these lines have not been introduced commercially. However using modern breeding schemes, it has been possible to produce hybrids with 6-8% oil and with yields similarly to those of commercial hybrids. For this reason, interest in the use of high oil corn in livestock feeding has increased.

The chemical composition of three different lines of high-oil corn as well as a normal corn are shown in table 1.

Little research has been conducted to establish the nutritional value of high-oil corn. In the early 70's, an experiment was conducted to test the energy content in high-oil corn. In this experiment growing pigs from 20 to 100 kg were fed either high-oil corn or normal corn. No differences in growth rates between pigs receiving high-oil corn or normal corn were obtained, but a significant improvement in feed efficiency was observed with high oil corn, indicating a higher energy content in high-oil corn. In addition, a higher deposition of linoleic acid was found in carcasses from pigs fed high-oil corn, and the carcasses from these pigs were softer.

In a European study protein quality of 11 different varieties of high-oil corn grown in the former Yugoslavia, was evaluated and compared to normal corn. From this study, it was concluded that the protein quality of high-oil corn is better than that of normal corn, mainly due to a greater content of indispensable amino acids.

Other experiments conducted in the 80's by Dr. Al Jensen and his graduate student Keith Adams at

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[1]*Prepared by Hans H. Stein, Dr.Robert A.Easter,Scott N.Carr, and Kevin Soltwedel, Department of Animal Sciences, University of Illinois.*

the University of Illinois evaluated the quality of the fat portion of high-oil corn. In these experiments, the fat digestibility in high-oil corn was compared to that of normal corn and of corn oil. The conclusion was that the digestibility of fat in high-oil corn is considerably lower than that found with pure corn oil (75% and 90% respectively). This was explained by the fact that the fats in corn oil are free and easy to digest, whereas the intact fats in high-oil corns might be bound within fiber structures and, hence, more difficult for the digestive enzymes to reach. However, it was also concluded that the energy value of high-oil corn is higher than that of normal corn.

In a series of experiments completed in 1994 at the University of Illinois by Dr. Bob Easter and one of his graduate students, Scott N. Carr, the nutritional value of three different lines of high oil corns was evaluated. The objective of these experiments was to determine how the extra oil content in high-oil corn effected the metabolizable energy content of the corns, and to evaluate the digestibility of the amino acids in high-oil corn as well as in normal corn. The chemical composition of these three varieties of high-oil corns are shown in table 1. Also shown in table 1 is the expected energy values in the high oil corns as well as in normal corn, when calculated from their chemical composition. A 2-5% increase in metabolizable energy was expected.

Diets were formulated with the four test corns and fed to growing pigs in a traditional metabolism study that involved total collection of urine and feces.

The results from this study are shown in table 2. The metabolizable energy content of all the corns were somewhat lower than expected. However the ME values for two of the high oil corns increased as expected compared to normal corn. This means that the pigs were able to utilize the extra oil efficiently for growth. However, it also appears from table 2 that one of the high-oil corns did not show the increase in energy value that was expected given the difference in oil content. The reason for this is unknown, but the key implication is that there are differences in the energy values from different varieties of high-oil corns, and that the energy value in high-oil corn can not be calculated directly from the oil content of that corn.

Evaluating the amino acid digestibilities in normal corn and a high oil corn using cannulated pigs, the investigators found that the amino acids in high-oil corn are digested at least as efficiently as those in normal corn. Thus, it is safe to use the same digestibility coefficients as in normal corn when calculating the amount of digestible amino acids in high-oil corn. However, in agreement with the earlier European studies, it was also found that the concentration of lysine along with other indispensable amino acids tended to be higher in high-oil corn than in normal corn. Consequently, the total amount of digestible amino acids is also higher.

The conclusion from these studies is that some lines of high-oil corn will contribute more energy to swine feeds, and by this, the overall feed utilization will be increased. The digestibility of amino acids in high oil corn is, at least, comparable to normal corn so no corrections are needed in this regard. Differences do seem to exist between different strains of high-oil corns. Therefore, it is important to know the genetic background of a specific strain of high-oil corn in order to calculate the nutritional value of this corn before feeding it.

Table 1. Chemical composition of normal corn (NC) and three different varieties of high-oil corn (HOC).

Nutrient	NC	HOC 1	HOC 2	HOC 3
Dry matter,%	87.0	87.0	87.0	87.0
Crude fat,%	3.71	5.89	8.26	8.83
Crude protein,%	7.31	9.05	7.48	8.26
Crude fiber,%	1.83	1.91	2.52	2.35
Ash,%	1.13	1.22	1.39	1.39
Expected ME, kcal/kg.	3420	3496	3573	3593
Expected ME, NC=0	100	102	104.5	105

Table 2. Energy values in normal corn (NC) and high-oil corn (HOC).

	NC	HOC 1	HOC 2	HOC 3
ME expected, kcal/kg	3420	3496	3573	3593
ME obtained kcal/kg	3269	3394	3326	3451
ME obtained, NC=100.	100	103.8	101.7	105.6

Nutritional Management of Early Weaned Pigs: a "New" Approach to Overcome Problems Related with Weaning

Introduction[1]

The U.S. swine industry is challenged to maintain or increase the consumption of pork. Two possible ways are through a reduction in price and through improvement of value. The major economic determinants of price include the number of pigs produced per sow per year and the growth rate and feed efficiency. The weaning period is typically characterized by a lag in piglet growth and development that may have negative impact on growth to market weight. Weaning includes several stress factors: environment, behavioral, immunologic and especially nutritional. At weaning, piglets are forced to change their feeding pattern from suckling to eating dry feed as well as their diet composition from sow's milk to a diet based on corn and soybean meal. The change from sow's milk containing easily digestible nutrients to a solid weaning diet of a different texture, composition, digestibility, temperature, smell and taste is a major challenge. Early weaned pigs (< 21 days old) especially, have problems facing this challenge due to an underdeveloped digestive capacity. This results in post-weaning stress which is characterized by limited feed intake, diarrhea, and atrophy of small intestinal villi. The consequence is reduced weight gain.

Nutritional problems related to early weaning have led to the development of special diets containing high amounts of expensive milk products. Additionally, management schemes have been developed through the years to improve performance of early weaned pigs. In the 1960s and 1970s, systems utilizing liquid diets with pigs less then one week old were developed but were not successful under practical conditions. Split weaning (weaning larger pigs in the litter earlier than smaller pigs) seems to be an effective mean for reducing days to market weight. Recently, the Medicated Early Weaning procedure was developed were high levels of medication are used to control the negative health factors often seen at weaning.

We are evaluating alternative nutritional and management strategies to ameliorate the post-weaning growth lag. The objective of this experiment was to investigate the use of a milk replacer diet for one week post-weaning where pigs were housed in an unique, environmentally managed building. We call this approach Nonmedicated Early Weaning (NEW). The novelty of this research lies in the design and operation of the nursery building which allow for automated feeding of liquid milk replacer while using environment cues to regulate piglet feeding behavior. In the past, the sanitary provision of milk replacers have been labor intensive. Our new building can rear 120 pigs at a time and requires only 30 minutes of labor per day for operation.

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[1]*Prepared by Ruurd T. Zijlstra, Dr. Jack Odle, and Dr. Robert A. Easter, Department of animal sciences, University of Illinois.*

The objectives of our initial research were to measure differences in feed intake, body weight gain and body composition among suckling pigs with ad libitum access to sow's milk, weaned pigs fed milk replacer or weaned pigs fed dry starter diet from day 18 to 25 of age. Furthermore, morphologic differences in the small intestine after feeding were characterized.

Materials and Methods

Eighteen days post-farrowing, seven litters of 12 pigs were split into weight blocks of 6 large (L) and 6 small (S) pigs. One pig from each weight block was killed and remaining pigs were allotted to: Treatment 1: Suckling (3 L, 2 S); Treatment 2: Fed milk replacer (1 L, 2 S); and Treatment 3: Fed starter diet (1 L, 1 S). Suckling pigs remained on the sow and served in this experiment as positive controls. In "theory" it would be hard for pigs to grow faster than when given unrestricted access to sow's milk in a small litter. Pigs fed starter diet (a high quality diet) were housed in groups in a conventional nursery. Pigs fed milk replacer were housed in the NEW nursery building with automated feeding of liquid milk replacer. The room temperature in this building was low (62 °F), while the pigs could voluntary move into heated, covered boxes at 90 °F. The milk replacer was supplied in the cold section of the building.

Pigs had ad libitum access to feed and were weighed daily from day 18 until day 25. On day 18 and 20, blood samples were taken for hormone (insulin and glucagon) analysis. On day 25, one pig of each treatment x weight block combination was killed. Samples were taken at 25, 50, and 75 % of the length of the small intestine and the whole body was ground. Small intestinal segments were analyzed by light microscopy and villus height and crypt depth were measured. The ground carcass was analyzed for nitrogen (protein), fat, water, and ash.

Results and Discussion

From day 18 until day 25, suckling pigs gained less than pigs fed milk replacer but more than pigs fed starter diet (**Figure 1**), with no difference in large and small pigs. Suckling pigs gained less protein and fat than pigs fed milk replacer but more than pigs fed starter diet (**Table 1**). This suggests that even unrestricted access to sow's milk results in nutritionally limited growth by day 18 post-farrowing. The extra gain in protein by milk replacer fed pigs indicates that the maximal potential lean growth is not realized with unrestricted sow's milk intake. Pigs fed the starter diet grew poorly compared to both other groups. Weight loss was observed directly after weaning, mainly because pigs weaned straight onto starter diet did not eat for two days. This observation was well correlated with the blood insulin and glucagon concentrations. Two days after weaning, the insulin ("eating hormone") over glucagon ("fasting hormone") ratio was lowest in pigs fed starter diet and highest in pigs fed milk replacer.

Total small intestinal weight and segment weights were higher in pigs fed milk replacer compared to suckling pigs (**Table 2**). This could mean that a higher flux of nutrients through the small intestinal wall leads to a better developed small intestine. Villi in the small intestine

were longer in pigs fed milk replacer compared to suckling pigs and pigs fed starter diet (**Figure 2**). This could lead to a greater adsorptive area in the small intestine of pigs fed milk replacer.

Overall, these results show that it is beneficial to feed pigs milk replacer for the first week post-weaning to overcome the post-weaning growth lag. However, it needs to be determined if the higher weight gain ultimately results in a shorter period to reach market weight and if indeed the system could be beneficial for the swine producer.

Table 1. Whole Body Composition.

Treatment	Day 18	<---------- Day 25 ----------> Suckling	Milk replacer	Starter diet	SEM
No. pigs	8	8	8	8	
Body weight					
- Protein (kg)	0.73 *	1.04	1.16 *	0.91 *	0.03
- Fat (kg)	0.55 *	0.80	0.94 *	0.52 *	0.04
- Ash (kg)	0.14 *	0.21	0.20	0.18 *	0.01
- Water (kg)	3.37 *	4.64	5.73 *	4.26	0.14
- Total (kg)	4.77 *	6.66	8.01 *	5.83 *	0.21
Percentage body weight					
- Protein (%)	15.36	15.68	14.45 *	15.60	0.16
- Fat (%)	11.43	12.03	11.73	8.76 *	0.34
- Ash (%)	2.91 *	3.12	2.47 *	3.07	0.07
- Water (%)	70.69 *	69.74	71.54 *	73.12 *	0.31

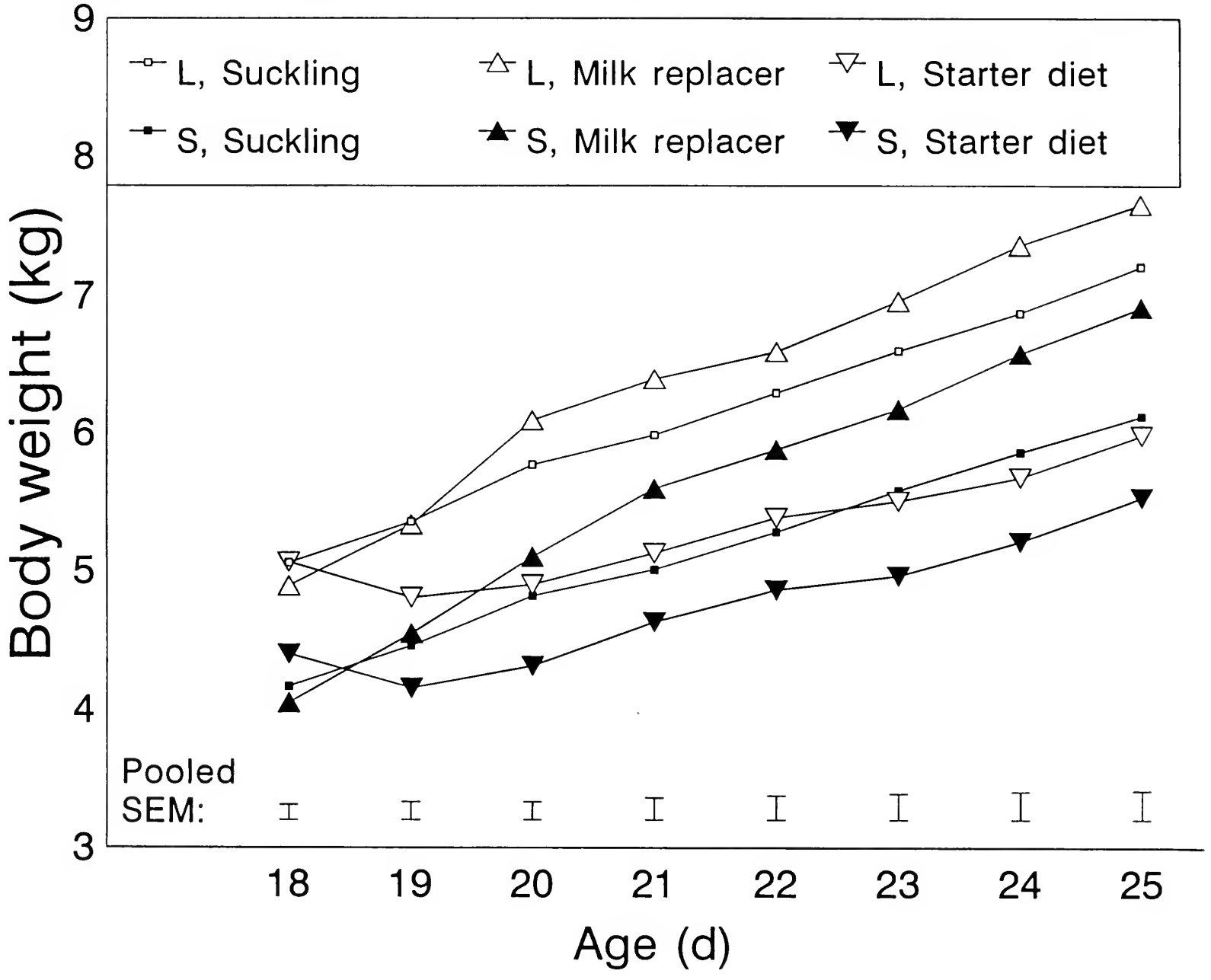
* Different from day 25 suckling pigs ($p < 0.05$)

Table 2. Weight and Length Measurements on the Small Intestine.

Treatment	Day 18	<---------- Day 25 ----------> Suckling	Milk replacer	Starter diet	SEM
No. pigs	14	14	14	14	
Total SI					
- Length (m)	5.72	7.08	7.27	7.33	0.19
- Weight (g)	124.78	181.61	250.79 *	202.51 *	4.84
Length/kg body wt	1.23 *	1.08	1.01	1.27 *	0.04
Weight/kg body wt	26.62	27.53	34.39	34.83	0.75
Weight/Length	21.93 *	26.12	35.02 *	27.66	1.08
Segment weight (g/3 cm)					
- Segment 25%	0.89	0.88	1.31 *	1.02	0.07
- Segment 50%	0.81	0.96	1.21 *	1.16 *	0.07
- Segment 75%	0.83	1.05	1.32 *	1.10	0.08

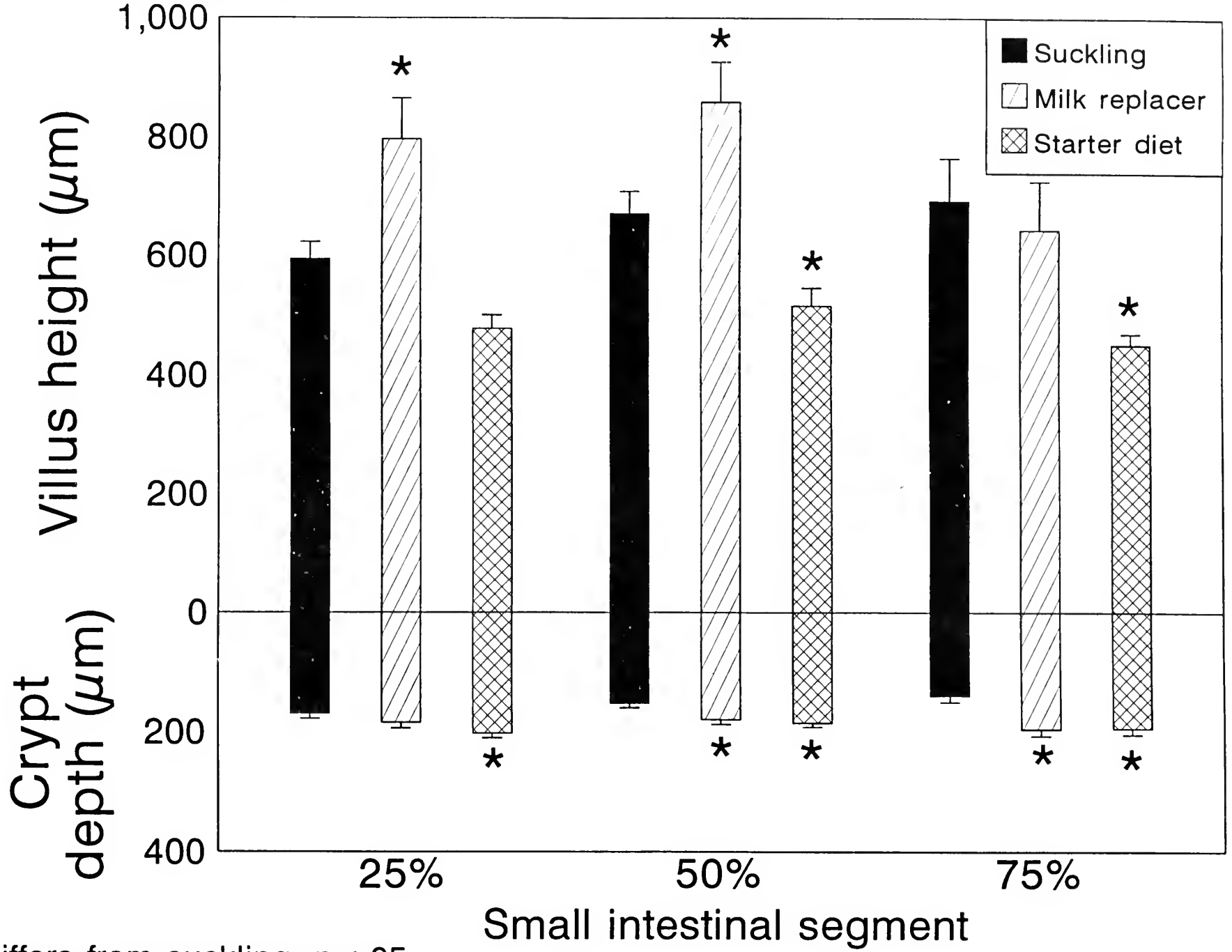
* Different from day 25 suckling pigs ($p < 0.05$)

Figure 1. Growth Profile from Day 18 to Day 25.



Weight block effect, $p < 0.05$; Treatment effect, $p < 0.05$, Weight block * treatment, not significant.

Figure 2. Small-Intestinal Villus Height and Crypt Depth.



* Differs from suckling, $p<.05$.

Metabolic and Blood Cytokine Responses in Early-Weaned Pigs Fed a Cereal- or Milk-Based Diet

Abstract

Metabolic and blood cytokine responses were evaluated in pigs weaned to either a soy protein-based (cereal) diet or a milk protein-based milk replacer (milk) diet. In addition, intestinal villus/crypt ratios were measured and goblet cells were counted to determine effects of weaning and diet on intestinal morphology. Seventy 21-day-old crossbred pigs were allotted randomly to the two diet treatments. Blood samples were taken on day 0 (weaning), and 1, 2, 5, and 7 days post-weaning and the samples were used for measurement of plasma insulin, glucagon, plasma urea nitrogen (PUN), glucose and serum NEFA. Plasma concentrations of the cytokine interleukin-1 (IL-1) were determined as a possible index of an immunologic response to weaning or diet. Villus/crypt ratios decreased over time and were higher in milk-fed pigs compared to cereal-fed pigs. Villus goblet cell numbers decreased for both groups throughout the study. At the end of 7 days, however, there were more goblet cells in the crypts of cereal-fed pigs while goblet cells numbers in the milk-fed pigs remained constant. Plasma insulin was higher in pigs fed the milk diet compared to pigs fed the cereal diet. Plasma glucagon was not different between dietary treatments, however average glucagon levels for all pigs increased from weaning through day 5. Plasma glucose concentration decreased during the study, however, milk-fed animals tended to exhibit a delayed decline. Serum concentrations of NEFA were not affected by either dietary treatment or day post-weaning. Dietary treatment did not affect IL-1 concentrations, however, IL-1 concentrations were increased for the first two days after weaning. The possibility that these two changes are linked through an immunophysiological mechanism is discussed.

Key words. Pigs, Weaning, Diet, Metabolic Hormones, IL-1, Intestine

Introduction

In an attempt to increase the number of pigs weaned per sow, many in the swine industry have adopted early weaning practices. There have been, however, many reports of reduced feed intake, decreased efficiency of feed utilization, and weight loss associated with early weaning. Even if pigs do not lose weight during this period, they often will not gain. This reduces the economic advantage of early weaning. It has been suggested that the immune system of the newly weaned pig may be reacting to some of the proteins in the weaning ration, in particular some soy proteins.

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Such an immunological reaction could contribute to the low performance seen in weanling pigs. The stress of the weaning process also contributes to poor performance. The phenomenon of post-weaning lag in pigs in not simple. There are many factors that act together to ultimately result in poorer performance. Considering that metabolic disturbances can be associated with intestinal alterations, the possible link between metabolism, the immune system and digestive disorders associated with weaning merits examination.

Accordingly, these studies characterized the metabolic response of 21-day-old pigs weaned to either a milk-based or cereal-based diet. These diets were used previously to determine pig growth; it was shown that pigs fed the milk diet had greater growth compared to those on the cereal diet (an average of 460 g/d weight gain in milk-fed pigs compared to 97 g/d weight gain in cereal-fed pigs; Jewell et al., unpublished data). In addition, plasma concentrations of interleukin-1 alpha (IL-1), a chemical messenger (cytokine) of the immune system that has been linked to decreased feed intake, was measured at timed intervals after weaning. Intestinal morphology was monitored throughout the study as an index of tissue integrity.

Experimental Procedures

Seventy crossbred pigs were used with an average weaning age of 19 days (range 17 to 22 days) and weaning weight of 6.3 ± 1.7 kg. Five pigs from each of six litters were randomly chosen and assigned to be bled and slaughtered at either weaning or 1, 2, 5 or 7 days post-weaning. Ten pigs (2 per day) from each of four additional litters were randomly allotted to be bled on the same day as those slaughtered. Within each litter and sampling time, pigs were randomly weaned to either a corn-soybean meal based diet (cereal) or a milk replacer diet (milk) containing dried bovine milk ingredients as the sole source of protein. Diets were offered ad libitum and feed intake measured daily.

Several tissues including the liver, spleen, small intestine and colon were removed from each slaughtered animal and the wet weight was recorded. Intestines were not emptied before measurements were taken. Small intestine tissue samples were also taken for villus and crypt measurements and to count the mucous secreting goblet cells. Goblet cells were counted in this study because previous reports indicate that goblet cell numbers are decreased upon early weaning in the pig and that the reduction in mucin resulting from lower numbers of goblet cells may expose the epithelial surface damage. Serum and plasma samples were taken to measure insulin, glucagon, glucose, serum NEFA, plasma urea nitrogen (PUN), and plasma IL-1.

Results

Feed Intakes. Average daily feed intake (g/pig/day) was measured on each day and summarized on each day of slaughter. Feed intakes for both diets increased throughout the study, however, intakes increased at a greater rate and to a greater extent for pigs fed the milk diet (Table 1).

Organ weights. Small intestine wet weight (g/kg BW) greatly increased for animals on the cereal diet. There was also an increase in small intestine wet weight for pigs on the milk diet, however, this increase was only seen through the second day post-weaning. A similar affect was noted with colon wet weights. Liver wet weights (g/kg BW) increased over time and were higher for pigs fed the milk diet. No differences were noted between treatments for spleen wet weights (Table 2).

Gut Morphology and Goblet Cells. Villus to crypt ratios decreased with time and were higher in milk-fed pigs when compared to cereal-fed pigs. Villus goblet cell numbers decreased for both groups throughout the study period, however, there were more goblet cells in the crypts

of cereal-fed pigs at the end of 7 days while goblet cells numbers in the milk-fed pigs remained constant (Table 3).

Blood Metabolites, Hormones and IL-1. Plasma glucose concentration decreased over time across diets. However, feeding the milk-based diet post-weaning resulted in higher glucose concentrations on day 1 through 5 (Figure 1). Plasma NEFA levels tended to be higher in cereal-fed piglets immediately after weaning, however this trend was reversed on d 7 (Figure 1). No effect of time or diet on PUN concentrations.

Plasma insulin concentrations were increased immediately following weaning in milk-fed pigs, however, insulin concentrations were the same for pigs on both diets by the fifth day after weaning (Figure 2). Plasma glucagon was increased across treatments over time (Figure 2) but glucagon was not affected by diet. Plasma concentrations of IL-1 were not affected by dietary treatment. However, plasma concentrations of IL-1 increased during the first 2 days post-weaning then declined (Figure 3).

Discussion

The present study evaluated two physiologic mechanisms that possibly influence performance in early-weaned pigs. First, we evaluated the effect of weaning and weaning diet on plasma concentrations of the cytokine IL-1 to determine if a systemic immune response was occurring. Second, given the acute switch in diet composition at weaning, we identified metabolic changes that occur in early-weaned pigs which likely influence growth.

Although increases in plasma IL-1 were noted for all pigs in response to weaning, these changes were independent of diet. The similarity of plasma IL-1 between pigs weaned to the different diets indicates that there was not a systemic immune response to dietary soy antigens. These results, however, do not eliminate the possibility that local intestinal inflammation occurs in response to soy proteins in the weaning diet. The antigenic nature of some soy proteins is well established in cattle and pigs. In addition, the intestinal immune system may be activated by changes in diet rather than specific antigens. Supporting this view, it has been shown that diet composition regulates the expression of important immune response genes. Cellular responses, including activation of T lymphocytes in the intestine by dietary antigens, may also be important in dietary effects on the intestine. Changes in diet composition can also cause changes in intestinal microbiological populations which can contribute significantly to post-weaning diarrhea.

Our results demonstrate clearly that diet-dependent metabolic changes accompany weaning in pigs as has been shown in other species. Rodent studies demonstrate that increases in circulating glucagon and decreases in circulating insulin accompany spontaneous weaning to a standard laboratory diet and that these changes occur quickly when rats are weaned abruptly and earlier when rats are weaned prematurely. Metabolic changes at weaning in rats are therefore tightly linked to dietary alterations rather than to age-related processes. Similarly, in the present study, plasma insulin concentrations were higher post-weaning in pigs receiving the milk-based diet compared to animals offered the cereal-based diet. Lack of an insulin response in animals weaned to the cereal-based diet could reflect either depressed feed intake or inadequate intestinal absorption or both. Regardless of the underlying mechanisms, growth is highly dependent on properly regulated insulin concentrations. Therefore, pigs weaned to the cereal-based diet are at a disadvantage compared to those receiving the milk diet and as a result, growth will be impaired.

The influence of weaning stress and its interaction with intestinal responses may have influenced the metabolic changes observed in these pigs. Changes noted in systemic IL-1 patterns may reflect stress associated with the weaning process. Plasma IL-1 has been implicated in decreased feed

intake and efficiency of feed utilization and decreased muscle protein synthesis in association with stress. These data show that IL-1 concentrations change inversely with feed intake suggesting a relationship between feed intake and IL-1 concentrations in post-weaning pigs.

The present study demonstrates that weaning animals to a cereal-based diet alters circulating pancreatic hormones which control nutrient availability for peripheral tissues. These changes correlate well with the decreased performance often reported in early-weaned pigs. The stress associated with the weaning process may also contribute to the lack of feed intake in pigs. The change from suckling to solid food may alter the intestinal microbial populations causing diarrhea and decreased performance. Characterization of interactions between metabolic parameters, changes in intestinal microbial populations, and fluxes in circulating cytokines which correlate with depressed performance in early-weaned pigs allows consideration of physiologic mechanisms that might be targeted to maintain appetite and growth during the first week after weaning.

Table 1. Average daily feed intake (g/pig/day)
for pigs weaned to either a cereal- or a milk-based diet

	Dietary Treatment[a]	
Period	Cereal	Milk
d0 to d1	143.5 ± 98.1	--[b]
d1 to d2	134.0 ± 98.4	253.5± 60.6
d2 to d5	259.2 ± 111.1	253.9 ± 99.3
d5 to d7	353.7 ± 105.8	451.8 ± 108.3

[a]Values are means ± the standard deviation.

[b]Intake data for this period were lost due to a computer malfunction.

Table 2. Organ weights (g/kg BW; mean ± SEM) of pigs weaned to either a cereal- or milk-based diet

	Organ			
	Int[a]	Col[b]	Liv[c]	Spl[d]
Day 0	21.9 ± 1.2	7.1 ± .8	9.5 ± .4	.9 ± .1
Cereal				
Day 1	24.6 ± 2.4	7.9 ± .6	10.5 ± .6	1.4 ± .5
Day 2	26.2± 3.7	10.7 ± 1.9	10.3 ± .8	.9 ± .2
Day 5	44.8 ± 3.9	21.1 ± .6	11.0 ± .8	.9 ± .1
Day 7	55.9 ± 2.0	20.7 ± 1.0	11.7 ± 1.5	.8 ± .1
Milk				
Day 1	24.0 ± .3	7.6 ± .6	11.1 ± .3	.9 ± .1
Day 2	29.0 ± 1.9	9.1 ± 1.0	12.9 ± 1.5	.9 ± .0
Day 5	30.2 ± 4.3	9.8 ± .7	13.3 ± .5	.9 ± .1
Day 7	30.4 ± 2.5	10.6 ± 2.1	13.9 ± .9	1.1 ± .1

[a]Int = small intestine; not emptied before measurements were taken.
[b]Col = colon; not emptied before measurements were taken.
[c]Liv = liver.
[d]Spl = spleen

Table 3. Villus/crypt ratios and goblet cell numbers (mean ± SE) in pigs weaned to either a cereal- or milk-based diet

	Villus/crypt ratio[a]	Goblet cells Villus[b]	Goblet cells Crypt
Day 0	2.6	10 ± 1.1	5 ± .3
Cereal			
Day 1	2.5	10 ± 1.7	5 ± .4
Day 2	1.4	6 ± 2.4	5 ± .9
Day 5	1.5	2 ± .2	5 ± .4
Day 7	.8	2 ± .5	8 ± .4
Milk			
Day 1	2.0	9 ± .9	5 ± 1.2
Day 2	2.6	6 ± 2.0	4 ± .2
Day 5	1.4	5 ± 1.7	5 ± .2
Day 7	2.0	3 ± 1.2	4 ± .6

[a]Villus/crypt ratios decrease with time and were higher in milk-fed pigs.
[b]Villus goblet cell numbers decreased for both diet groups.
[c]Cereal-fed pigs had more crypt goblet cells on day 7 while crypt goblet cell numbers remained constant in milk-fed pigs.

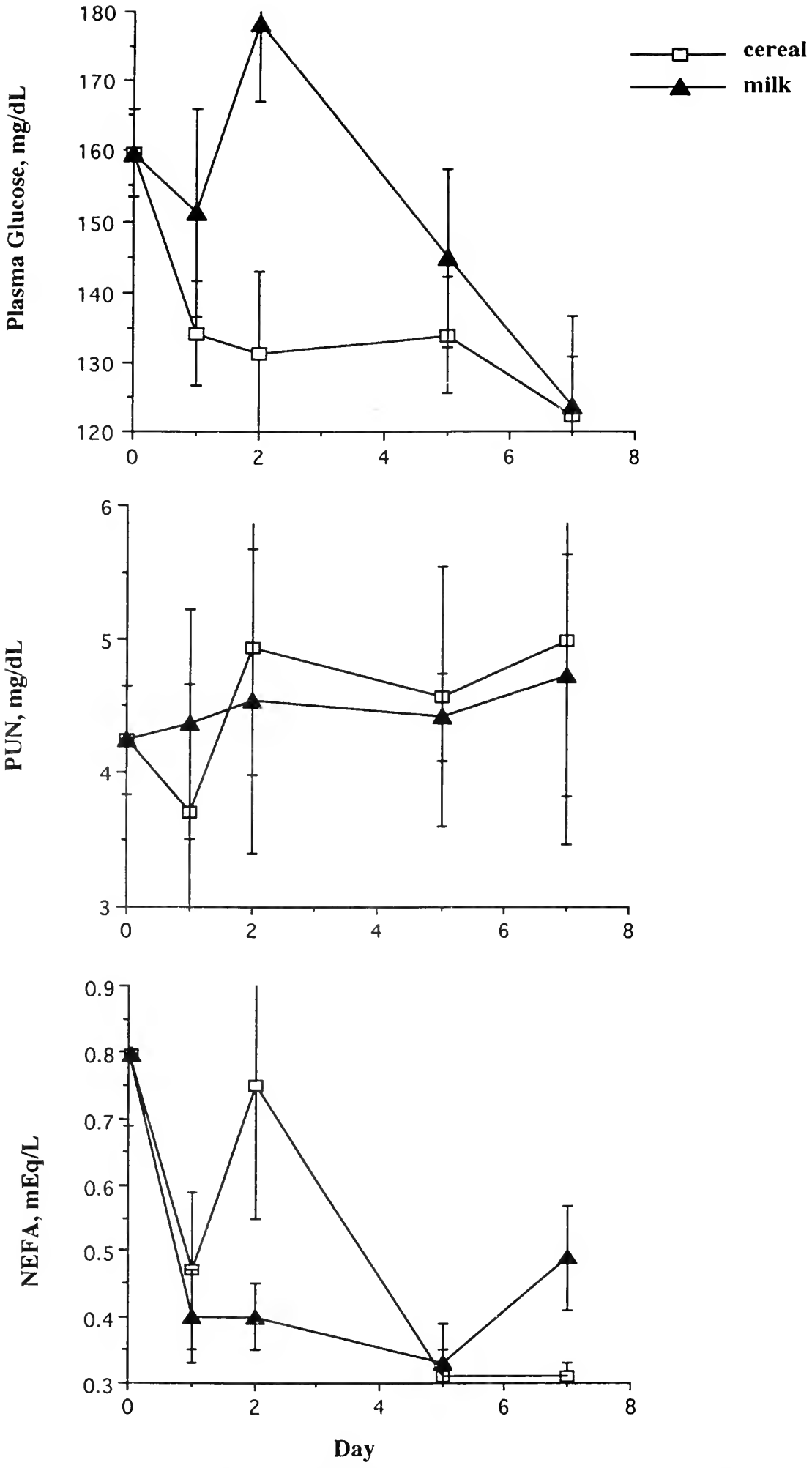

Figure 1. Plasma glucose, PUN and NEFA of 21-d pigs weaned to either a milk- or cereal-based diet.

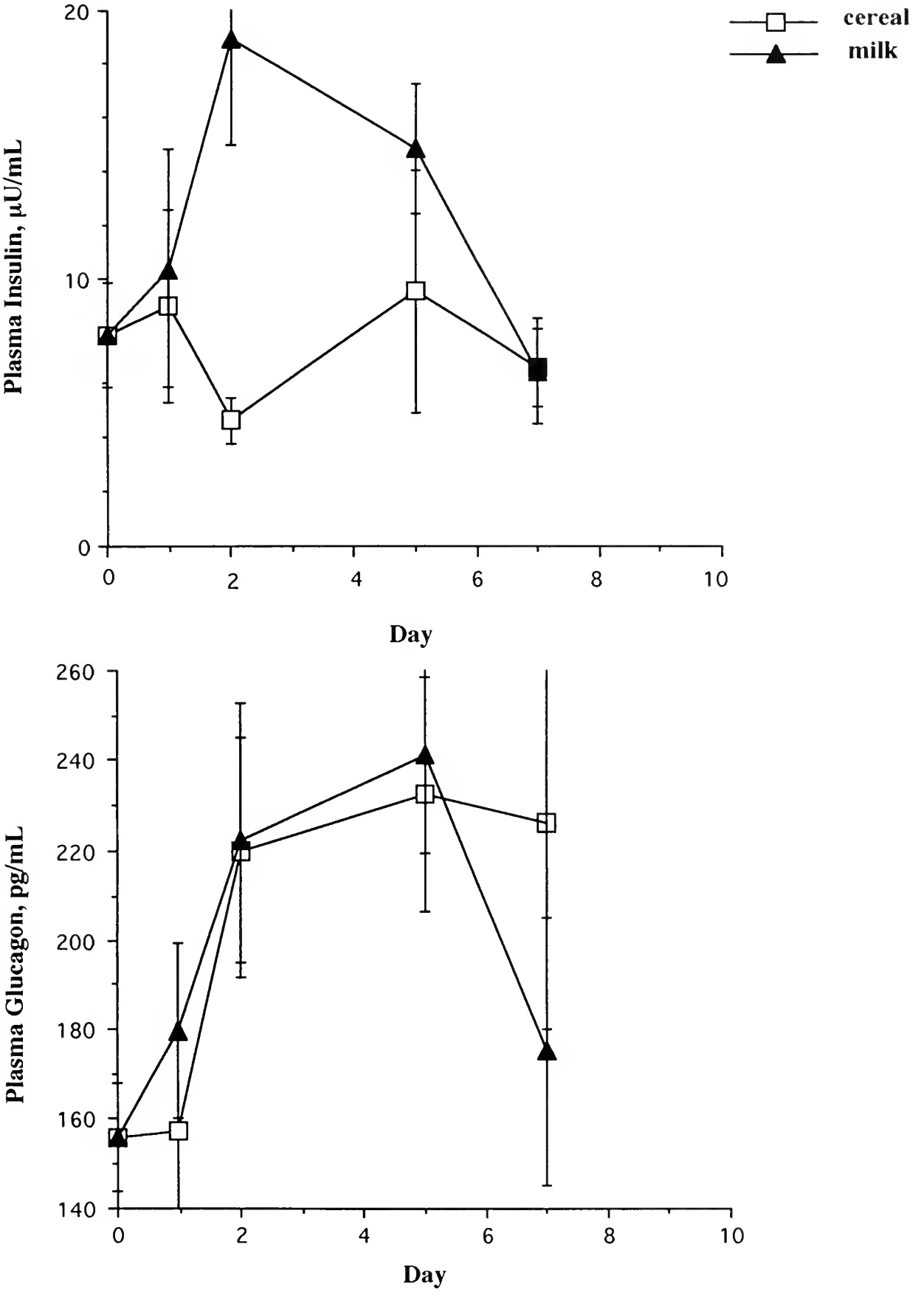

Figure 2. **Plasma insulin and glucagon of 21-d pigs weaned to either a milk- or cereal-based diet.**

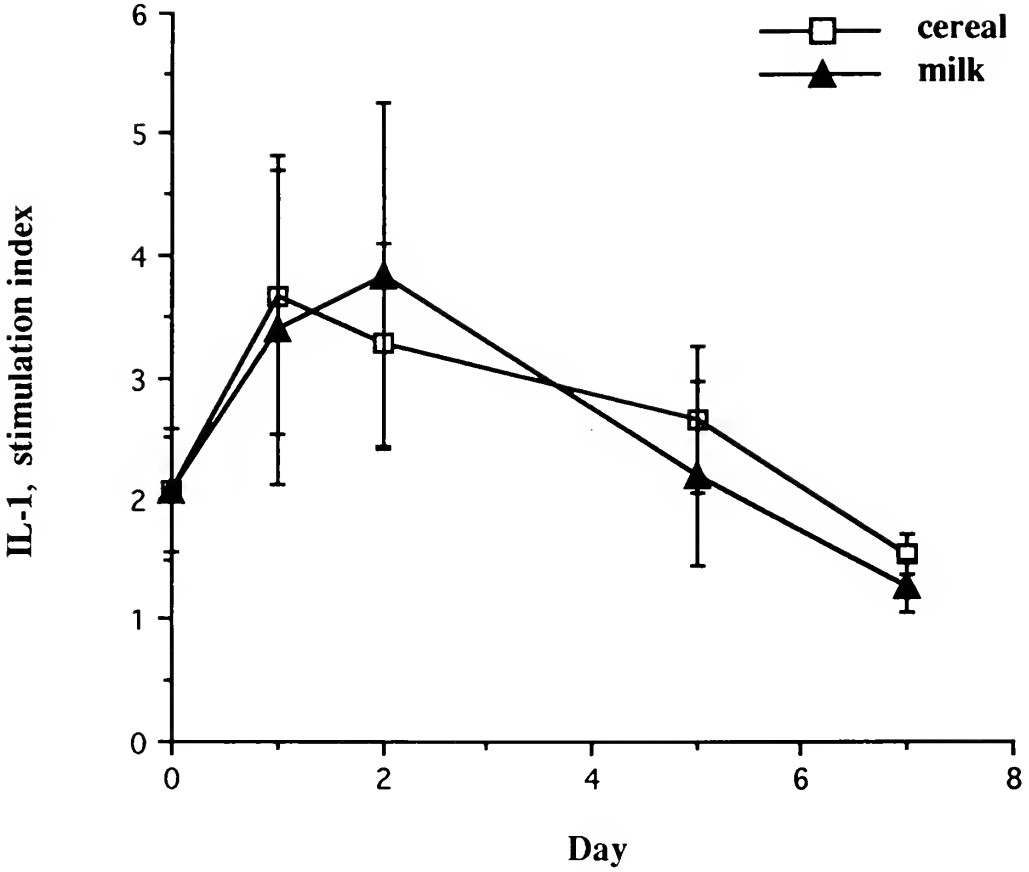

Figure 3. IL-1 concentrations in 21-d pigs weaned to either a milk- or cereal-based diet.

Reducing Heat Stress in Gilts and Sows

Background.[1]

Appropriate environmental management is an important factor in animal management practices, in terms of welfare as well as productivity. Mammals have means of thermo regulation which allow them to maintain a homeostatic body temperature. They may utilize behavioral and/or physical thermo regulation. Animals will respond to heat stress with functional changes in an attempt to increase heat loss in relation to heat load. Adjustments will be implemented beginning with those that require lower energy expense, such as altering cardiovascular output that will increase the animals surface temperature, and behavioral thermo regulation. Due to the inability of pigs to sweat they must depend on panting for evaporative heat loss, which is metabolically more expensive than evaporative heat loss from the body surface that occur with sweating. If a conductive heat sink is available to pigs in a hot environment then conduction from the animals surface may serve the same purpose as evaporation in sweating animals.

Behavioral thermo regulation can be observed when environmental temperatures approach either extreme of the thermo neutral zone. Heat stress is of greater concern than cold stress, as heat stress can be extremely detrimental to welfare and economic production over a narrower range of temperatures. Heat stress begins at a point where environmental conditions and temperature become high enough to induce one or more thermoregulatory processes in an attempt to retain the homeostatic condition. The results of heat stress may range from decreased feed intake and efficiency of growth, reproduction and general unthriftiness to hyperthermic death. It appears that acute and scattered heat periods, with intersperced periods of thermoneutrality provides an opportunity for the detrimental effects of heat stress to be physiologically compensated for; however, extended periods of heat stress can quickly lead to exhaustion and death.

Selection of a more appropriate thermal micro-environment and changes in posture and body position to adjust body surface area in contact with environmental temperatures represent two common methods to behavioral thermo regulation. One method of achieving optimum welfare and production in environmental management is to allow the animal to choose its own micro-environment and evaluate the appropriateness of those choices. By evaluating these choices, it may be possible to provide effective choices to animals in confinement situations that would otherwise restrict their ability to behaviorally thermoregulate.

In order to determine if a pig will make a choice between cooling systems and if that choice is of physiological benefit to the animal, two experiments with farrowing sows and breeding gilts respectively were conducted.

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[1]*Prepared by Rebecca P. Bull, Dr. Paul B. Harrison, Dr. Carmen Santana, and Hans H. Stein, Department of Animal Sciences, University of Illinois.*

Procedures.

In experiment 1, a "thermal pillow" was attached to the elevated plastic coated flooring in farrowing crates at one side of the centrally located feeder allowing the sow to lie with her head and ear on the pillow or on the opposite side of the feeder directly on the plastic coated floor. The "thermal pillow" was constructed of galvanized iron pipes (1.3 cm in diameter) and elbows to form a 0.31 X 0.31 m square pad. Tap water continuously was circulated through the pillow at a temperature between 19 and 23 degree C (64-73 F). Control animals also had access to the pillow but no water was circulated through it, and the temperature, therefore, remained in equilibrium with room temperatures which was held between 32 and 35 degree C (90-95 F). Rectal temperatures as well as temperatures of the eye, ear and mammary area were measured, and respiratory rate was determined in control sows as well as experimental sows.

In experiment 2, 42 breeding gilts (130-150 kg) were used to evaluate the voluntary use of three different cooling systems when environmental temperatures ranged from 32-37 Degree C (90-99 F) during a 10 hour day period. The three cooling systems used were conductive cool pads, snout coolers, and drip coolers. The effectiveness of each system in dissipating heat load, was determined by rectal temperatures and respiration rate taken at three different times during the day. Animal behavior was recorded during videotaping.

The drip cooler used was a commercially available 3 mm tubing drip cooler. It was installed to drip continuously at an average rate of 56 ml/minute. Average water temperature during the heat stress period was 35 degree C (95 F)

Snout coolers were constructed of a 61 cm section of a PVC pipe with a 90 degree elbow at the bottom to direct cooled air into the stall at a height of 30 cm. off the floor. 30 cfm cooled air (30 degree C) was delivered to each gilt. The gilts could position themselves to have the snout cooler blowing on them from standing, sitting, and lying positions.

The conductive cool pads were constructed of 6 mm galvanized pipe and elbows to form a pad with the dimensions of 89 by 46 cm. Hose fittings on input and output pipes allowed for the delivery and exit of cooled (18-22 C) water from the pad.

Results

Data from experiment 1 indicated that the conductive cooling pillow is behaviorally preferred in the hot environment. The respiration rate in experimental sows was only 89 % of that observed in control sows indicating that the cool pad was of some thermoregulatory benefit during the first ten days of hot environment exposure. However, body temperatures remained elevated in experimental sows kept in the hot thermoenvironment, indicating that the cool exposure from the pillow was not enough to decrease temperatures in these sows. Milk production and litter weight gain was unaffected of the experimental procedures.

In experiment 2, it was revealed that the behavioral preference of the gilts was strongly for the use of cooling systems. Among the three systems, the cooling pad was the preferred one, this system was chosen 58 % of the times pigs chose to use a cooling system. The snout cooler was the least preferred among the systems (13.5%), with the drip cooler being the intermediate preference (28.6%).

Rectal temperatures in non-cooled pigs were 39.6 degree C. Only in pigs using the cooling pad was rectal temperatures decreased, whereas no reduction was observed in pigs using either the snout cooler or the drip cooler. The respiration rate of pigs using the cooling pad

was reduced compared to non-cooled pigs (72.7 and 103.2 rpm respectively). No decrease in respiration rate was observed upon the use of snout coolers or drip coolers.
These observations indicate that pigs will choose to use the cooling pad when given the opportunity and that the cooling pad is the only system that can efficiently decrease rectal temperature and respiration rate in heat stressed pigs.

Conclusion.

Results from the experiments suggest that the smaller (31 by 31 cm) cool pillow does not provide detectable physiological benefits during heat stress conditions, although the sows will use the pillow. The use of the pillow may indicate that the sows do derive some comfort from its use. A larger surface area of the pillow may improve its effectiveness.
The behavioral preference experiment was conducted using a larger (89 by 46 cm) cooling pad. Results from that experiment showed that pigs do prefer the use of a cooling system under heat stress. Animals will use the cooling pad as their first preference, the drip cooler as their second and the snout cooler as their third preference. Physiological measurements during heat stress strongly suggests that the cooling pad provides physiological advantages in combating the detrimental effects of heat stress.
Incorporating conductive cool pads into production environments may increase the animals ability to maintain a normal body temperature and respiration rate in heat stress conditions and thus maintain optimum production via maintained feed intake, reproductive efficiency and growth potential. Additionally, these experiments suggest that the use of cooling systems may increase animal welfare since gilts will voluntarily choose to use these systems.
In conclusion, the conductive cool pad provides a relatively inexpensive, environmentally safe and potentially low maintenance method of providing zone cooling that has been shown to be the choice of pigs while keeping rectal temperatures and respiration rates in a normal range so that the animals can partition energy to more profitable growth and reproductive processes.

The Pork Quality Audit

Background.[1]

Within the U.S. business sector, there is an interest in "Quality". A major reason for this is the tremendous success for the Japanese in adopting the "Quality Religion" and in using this to manufacture dependable, doable and defect-free goods which meet consumer needs. Typically, the livestock and meat industries have perceived quality as being associated with descriptive terms such as "freshness", wholesomeness", and "grade". However in the 1990's, needs for improvement in "quality" of meat-animal products are causing livestock producers , packers, processors, purveyors and detailers to reconsider their production practices in terms of which decisions affect value/desirability of live weight slaughter animals (swine, cattle, calves and sheep), of their dress-off/offal items, of their carcasses, of their primal/subprimal cuts, and of their steaks, chops, roasts, processed products and fresh ground products.

Currently, the U.S. pork industry faces challenges similar to those of the U.S. sector in general. For every barrow/gilt slaughtered, an unknown amount of money is lost due to correctable quality shortfalls. These "quality deficiencies" must be identified, measured and then addressed. The pork industry cannot expect increases in prices for its products/by-products when quality does not warrant such increases. Quality defects represent lost revenue opportunities for the industry. Currently, an unknown amount of money may be lost to elements/entities/sectors of the pork production system because of failure to prevent nonconformity or of failure to produce high-quality slaughter pigs, carcasses or dress-of/offal items. With more complete knowledge of the extent and causes of these defects, pork producers can seek ways through improved genetics and management techniques to reduce or eliminate these quality defects.

Objectives.

The Pork Quality Audit was conducted to:

A. establish a baseline for quality shortfalls and identify targets for desired quality levels.

B. To quantify numerically, and monetarily, the incidence of quality defects in U.S. slaughter hogs.

Procedures.

The audit was designed to be conducted in two phases in an effort to address its objectives.

Phase 1: Research review. A number of surveys and research trials have been conducted which have addressed pork quality issues and perceptions. Results from these studies and any

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[1]*Prepared by Dr Floyd McKeith, Judy Heavner and Hans H. Stein, Department of animal sciences, University of Illinois.*

other available data-sets have been gathered and reviewed. The review helped identify traits that affect quality and/or impact defects associated with pork quality. In addition, it gives the pork industry an indication of the current state of the knowledge available regarding pork quality.

Phase 2: Data acquisition. Once the channels of communication between researchers and elements of the pork industry had been established, a survey instrument was developed to conduct interviews with people from individual sectors and segments of the pork chain. When accessible, records from the various sectors were analyzed to add to the data-set regarding pork quality. Data were analyzed to evaluate the factors affecting value and the relative impact of each type of defect. In addition, the frequency of the quality defects were quantified when possible. Also, the costs of the defects in the various sectors were estimated.

Results.

Phase 1: The research review summarized results from more than 100 studies involving pork quality and covers factors which influence quality in the various sectors of pork production and marketing. Factors including genetics, transportation, fresh meat storage, carcass chilling, etc. are discussed in detail as each relates to specific influences on pork quality. The research review provides a base for identifying factors which impact nonconformity in pork quality.

Phase 2: Phase 2 of the audit established baseline information for the different sectors of the industry. Results suggest that the bulk of the hogs are located within 150 miles of the plant and that they are purchased from individual producers using some form of grade and yield purchasing program. Approximately 30 % of the pigs purchased lacked uniformity. Slaughterweights for the majority(66%) of the pigs ranged from 220 to 260 lb and the dressing percentage for 86 % of the pigs ranged from 72 to 76 %.

Live hog and carcass condemnations averaged approximately 0.2 % of the slaughter hog supply. The largest component of the condemnations (38%) were animals arriving at the plant dead or those that died during lairage.

Skin problems were identifier by the packers as a problem with 15% of the slaughter hog supply. Dehairing problems accounted for 52% of the skin problems, and parasites accounted for an additional 21 % of the skin problems.

Over 13% of the hogs slaughtered required carcass trimming to remove external-surface defects. Abscesses and bruises accounted for 57% and 22% of the required trimming, respectively.

Results from the fabrication portion of the survey revealed that 80% of the pork carcasses had sufficient muscling. Approximately 36% of the pigs had 1.2 inches or more of back fat, and the average percentage of muscling was 49.5%

The majority of pork cuts are trimmed to have either no fat trim, 0.13 inch fat trim or 0.25 inch fat trim indicating that packers are presenting cuts that meet the demand for reduced amounts of external fat trim. In order to meet the desired fat trim levels, approximately 28% of the boxed pork required minimal trimming, 54% required intermediate trimming, and 18% required excessive trimming.

Results from the survey determined that 92% of the carcasses had sufficient marbling. However, 13-15% of the carcasses had loins or hams that exhibited two-toned muscle color.

In addition, 10% of the carcasses were classified as PSE and 4% were considered DFD by plant personnel. The incidence of ecchymosis (blood splash) was 9.9 and 9.4% for hams and loins, respectively. Additional trimming to remove external-surface defects was required during fabrication on 10% of the carcasses. Abscesses and bruises accounted for approximately 57% of the required trimming losses.
The survey's result indicate that the average US market hog weighs 247 lbs, has a dressing percentage of 73.4%, has 1.1 inches of bachfat and has a muscling percentage of 49%.

Packer economic losses from quality defects were identified. The total cost of nonconformities at the packer level was 10.08 dollar per pig marketed. Of this, the cost of carcass and partial condemnations was about 1 dollar while excess backfat and seam fat costs 3.38 dollars.
Water holding capacity was lower than desired for nearly 20% of the raw materials. Processors manufacturing hams reported excess fat on the hams approximately 38% of the time. Processors reported that 6.6% of the bellies were too thin for bacon production. Furthermore, 70% of the processors reported that some trimming was required in order for the belly to meet specifications. Problems related to color or trimmable defects in belies were relatively minor.
Total costs of non-conformities at the processor level resulted in the loss of 2.32 dollar per hog slaughtered. Failure to meet trim specifications accounted for approximately 45 % of these costs.
Responses of purveyors revealed that a major problem with the trim being presented to the purveyors is the excessive fat content compared to that in the purchase specifications. Purveyors indicated that approximately one-fourth of the trim they receive has excessive fat. This generates additional expense because extra lean is needed to blend with the fatty portions in order to attain the desired fat composition.
Personnel from retail food chains were surveyed to gain an understanding of the quality of pork being presented to consumers. Quality problems of greatest concern included: excessive color variation, too much purge, inadequate shelf-life, and lack of uniformity/consistency of cuts. The concerns of the retail group were similar to those of the other pork sectors indicating that the pork quality problems are not being corrected at the earliest level of the chain and instead, are being passed along the distribution chain.
Interviews with American Meat Institute (AMI) personnel identified some very positive attributes of pork: 1) Pork is competitive in price with poultry, 2) Product development has enhanced pork's image, and 3) The pork industry has pushed the development of lean products. They also identified some areas that the industry should continue to work on: 1) Reduce fat, 2) Maximize color and water holding capacity of the muscle, and 3) improve the consistency of the products available.
Officials from the Food Marketing Institute gave a similar response to that of AMI. They identified fat and lean quality (color and water holding capacity) concerns as factors for the industry to improve. In addition, personnel from the National Restaurant Association suggested that consumer perception of fat is a negative for pork in the marketplace.
The major quality problems for U.S. pork in the export marked were identified by officials

from the Meat Export Federation (MEF). They suggested that there is excessive variation in the quality and freshness of U.S. pork. Specifically, the incidence of PSE is too high. Furthermore, U.S. pork lacks freshness because of inadequate product packaging and product temperature control. MEF officials also expressed concern relative to the lack of uniformity of pork in meeting cutting and trim specifications; specifically, inconsistent sizes and weights. Excessive external fat and inadequate muscling were additional problems for U.S. pork at the export markets. MEF officials also observed reduced consumer appeal related to residues found in U.S. pork. The amounts of residues which are actually found in U.S. pork were low, however, the negative perception related to residues hurts the image of U.S. pork.

Conclusion

In order to enhance the value of pork or to reduce the costs of moving pork through the chain, a number of current quality concerns have to be corrected. Data from the audit suggest that concerns about excessive fat, color, waterholding capacity, and consistency of products occur in almost all segments of the pork chain. These non-conformities account for more than 50 % of the quality related costs though the chain. Eliminating these non-conformities could enhance the value of pork.

At the farm level, the following step will contribute to this:

1. Decreasing the level of back fat in market hogs.
2. Increasing use of genetic lines that provides the desired levels of waterholding capacity and color in the finished products.
3. Increased uniformity, that is, marketing of hogs who are equal in size, genetic background, muscling percentage etc.
4. Avoid marketing of hogs containing drug-residues.

Ctyokines: A Missing Link Between Immunology and Physiology

Introduction

Disease and food intake control have long been two of the most important issues in swine research. Although animal scientists have long recognized that sick animals fail to eat and therefore grow, only recently have they begun to understand the relationship between growth and disease. It is now appreciated that pathogenic agents (bacterial and viral) induce cells of immune system to produce proinflammatory molecules called cytokines. The macrophage is the first line of defense against invading pathogens. As shown in Figure 1, these cells release at least three major cytokines when exposed to pathogenic agents. These include interleukin-1 (IL-1), interleukin-6 (IL-6) and tumor necrosis factor-α (TNFα) These inflammatory molecules act locally to amplify the cellular immune response (e.g., T lymphocyte proliferation), but also enter the circulatory system where they are distributed throughout the body to act on a number of behavioral, physiological and neuroendocrine targets.

One of the major targets for these cytokines appears to be the central nervous system (CNS). In fact, it is now clear that cytokines are important messengers that are used to inform the brain that an infection has been established outside the CNS, in an organ such as a popliteal lymph node. This information from the immune system is integrated by the brain, which subsequently responds by inducing systemic inflammatory responses such as fever, corticotropin-releasing hormone (CRH) release and anorexia. In essence, these molecules are what make you and I feel "sick." Unfortunately, this important concept has not been extended to swine. However, this type of basic information is critical for understanding the immune system's contribution to the composition and retardation of growth in swine.

As a model system for bacterial infection, we have begun to test this hypothesis in pigs by injecting lipopolysaccharide (LPS), a molecule found on the outer surface of many

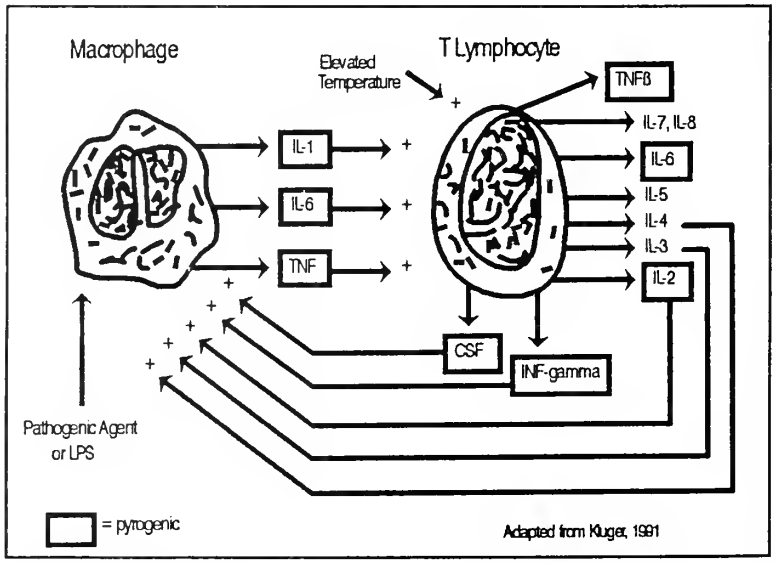

Figure 1. Pathogenic agents stimulate cells of the immune system to synthesize and release cytokines.

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[1]*Prepared by Brian N. Finck and Emily J. Warren, Graduate Research Assistants, and Rodney W. Johnson, Assistant Professor, Behavioral Sciences, Department of Animal Sciences, College of Agriculture, University of Illinois at Urbana-Champaign.*

bacteria including *Escherichia coli*. It is now clear that pigs respond to an acute injection of LPS by reducing food intake and activity and developing a fever (Johnson and von Borell, 1994). Although the effects of LPS are attributed to a cascade of cytokine synthesis and release, it is unclear whether they make pigs "feel sick" by targeting peripheral or central sites. To test this, recombinant porcine TNFα was injected directly into the CNS. Remarkably, the central administration (i.e., into the CNS) of TNFα induced responses that were virtually identical to those induced by peripheral immune stimulation with LPS (Warren et al., in press). Based on these observations, it seems reasonable to postulate that the effects of peripheral immune stimulation are at least partially regulated by cytokines in the CNS. These efforts and their relevance to swine production are the focus of this report.

Cytokines in the CNS: Can they induce sickness?

In an initial experiment we took advantage of a well-documented system for inducing cytokine production by injecting LPS. Twenty barrows (20-25 kg BW) were surgically prepared with indwelling jugular catheters and temperature-sensitive radio transmitters. Pigs were injected with saline or *Escherichia coli* LPS [serotype K-235 (.5, 5 and 50 μg/kg BW)] intraperitoneally (n=5). Behavior was measured during 10 min tests as previously described (Johnson et al., 1994). For a test, pigs made hungry by a 12-h fast were provided *ad libitum* access to food for 10 min just before administering the LPS and again 2, 4, 8, 12 and 24 h later. Food intake and time spent standing, lying, eating and somnolent were measured to provide an index for "sickness." In addition, serial blood samples were collected and plasma cortisol concentration was measured by radioimmunoassay.

This initial experiment was conducted to quantify several important behavioral and physiological effects of peripherally injected LPS. Consistent with previous reports, pigs injected with LPS consumed less feed and were inactive and somnolent. The effects of LPS on food intake are represented in Figure 2. At 2 h, pigs injected with LPS consumed less feed compared to saline ($P<.001$). This effect was still evident at 4 and 8 h, but the duration of this effect was dependent on the amount of LPS injected. The behavioral effects of LPS were accompanied by profound changes in metabolic and neuroendocrine responses. As hypothesized, acute administration of LPS induced an increase in body temperature ($P<.05$) and a dose-dependent increase in plasma cortisol concentration ($P<.05$).

Most of the effects of LPS are attributed to its ability to elicit cytokine production by macrophages. Although porcine macrophages produce abundant quantities of TNFα *in vitro* in response to LPS (Dunham et al., 1990; Baarsch et al., 1991), the effects of this cytokine in swine are not at all clear. In laboratory animals and humans, TNFα causes a plethora of behavioral, metabolic and neuroendocrine responses. It is the first cytokine to be released, and as a matter

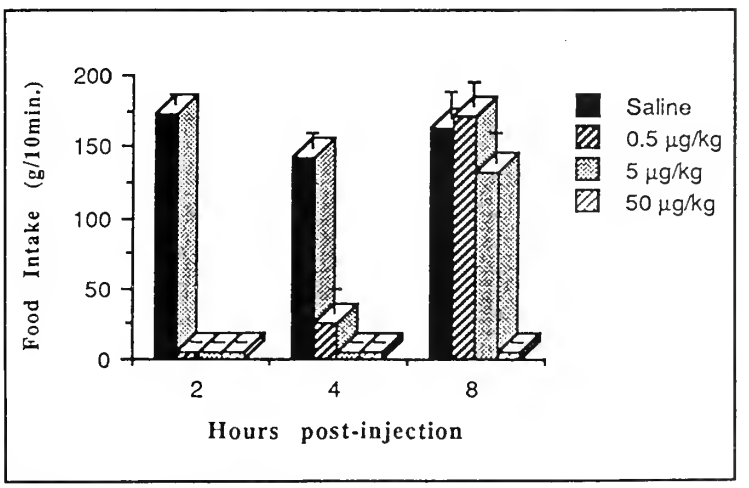

Figure 2. Peripheral injection of LPS from *Escherichia coli* causes anorexia in swine.

of fact can induce the release of many of the other cytokines shown in Figure 1. Therefore, although TNFα is considered the principal mediator of the host response to bacterial infection (Beutler and Cerami, 1989) in several other species, no information on these effects is available in pigs.

To begin to address this issue and determine if TNFα can act directly within the CNS of pigs to induce responses reminiscent of sickness, in a second experiment recombinant porcine TNFα (a gift from Dr. Michael Murtaugh, University of Minnesota) was injected intracerebroventricularly (icv). A cannula was placed stereotaxically in the left-lateral cerebral ventricle as previously described (Johnson et al., 1994). The flow of PBS by gravity indicated the cannula was icv. Saline or TNFα (5, 50 and 100 ng/kg BW) was injected icv in 6 pigs after a Latin-square and behavior and plasma cortisol were assessed as in the first experiment.

Results indicated that icv injection of TNFα induced behavior and neuroendocrine responses similar to those observed following peripheral injection of LPS. Following treatment with TNFα pigs were anorectic, inactive and somnolent ($P < .05$). The effects of TNFα on food intake during the 10 min tests are shown in Figure 3. These results were not caused by endotoxin contamination because heat-inactivated TNFα (100 ng/kg) was ineffective. Sickness behaviors were evident at 2 h, but their duration depended on the amount of TNFα injected. These behavioral effects were accompanied by an increase in plasma cortisol concentration. At 1 h, TNFα increased cortisol concentration compared to saline. This response peaked at 2 h, but the duration was dose-dependent.

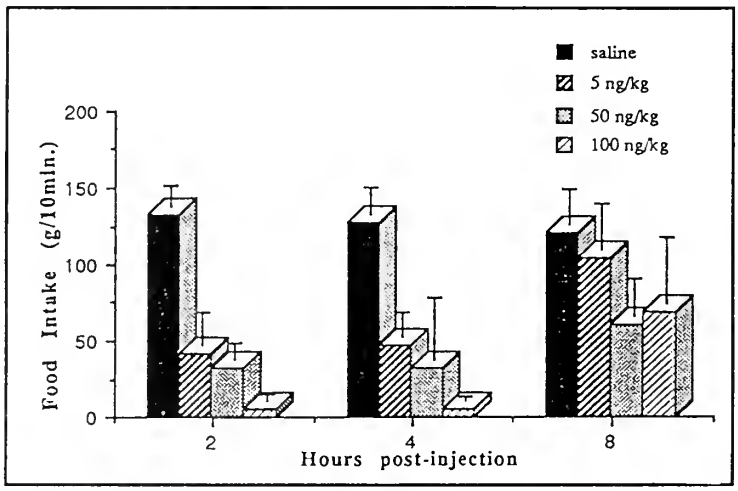

Figure 3. Recombinant porcine TNFα injected into the lateral cerebral ventricle causes anorexia in swine.

Conclusion

These data indicate that TNFα injected into the CNS is sufficient to induce behavior, metabolic, and neuroendocrine responses that are reminiscent of sickness. The behavioral and physiological effects were strikingly similar to those caused by peripheral immune stimulation by LPS. Because the effects of LPS are attributed to a cascade of cytokine synthesis and release, these data may be interpreted to suggest that the effects of peripheral LPS are mediated in part by the central actions of cytokines.

These data indicate that cytokines can induce behavioral and neuroendocrine responses in swine. Moreover, they demonstrate that the immune system is inextricably linked with other physiological systems, and therefore it is likely that changes in one system evoke changes in the other. This unified view has broad implications for swine production as cytokines are

constitutively expressed in seemingly healthy pigs. Swine have the genetic potential to reach mature market weight in 145 days, yet in the United States the average is 180 days. The factors that contribute to this lag in growth have not been fully defined or characterized, but the immune system is likely to have an important role. A better understanding of the biological actions of cytokines is needed before the immune system's contribution to growth and performance can be fully appreciated.

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The Endocrine Involvement in Reproductive Problems in Sows

Background.[1]

The endocrine involvement in impaired reproduction in sows is not completely understood, but since the incidence of post weaning anestrus has been shown to be increased in sows fed low levels of energy during lactation, a link between nutrition and reproduction has been suggested. In addition, it is known that feed restriction during lactation results in a decreased release of the hormone LH which might be related to lower insulin levels in feed restricted sows compared to ad. libitum fed sows. Also, the thyroid hormones are involved in reproduction and they have a permissive role in ovarian function, but it has not previously been demonstrated whether lactation energy intake effects the concentration of thyroid hormones and if these hormones are related to the onset of estrus after weaning. Low feed intake during lactation has also been shown to decrease the serum concentrations of insulin-like growth factors I and II (IGF-I and IGF-II), However, it is unknown whether the concentrations of these growth factors also decreases in milk and in the follicular fluid of ovaries.

Objectives.

In order to investigate the above mentioned areas, three studies with primiparity sows were conducted. The main objectives of these studies were:

1. To measure serum concentrations of thyroid hormones during and after lactation in sows fed a low energy diet during lactation.
2. To establish a possible relationship between serum and milk concentrations of IGF-I and IGF-II during lactation, and between serum and follicular fluid levels of these growth factors after weaning.
3. To determine if low lactation energy intake negatively effects ovarian steroidogenesis after weaning.

Results.

The first experiment showed that feed restriction during lactation do affect the serum concentration of thyroid hormones. However, it was also shown that after weaning, the serum levels of thyroid hormones in restricted fed sows increases rapidly to reach the level of ad. libitum fed sows. Therefore, it still remains to be outlined how this decrease is associated with reproductive performance.

The second experiment showed that feed restriction during lactation decreases serum and milk concentrations of IGF-I and and IGF- II, whereas no effect was noted on the follicular fluid concentration of neither of the two growth factors. Thus, IGF-I and IGF-II do not seem to be directly involved in changes in the reproductive performance of sows

Results from the third study indicated that sows fed low energy levels during lactation may experience an ovarian malfunction due to a decrease in the numbers of steroidogenic enzymes after weaning, which in turn might be responsible for the reproductive problems.

All the three studies have helped increasing our understanding of the reproductive problems associated with low energy intake during lactation, but more research in the area is still needed.

---

[1]*Prepared by Mary Carmen Rodriguez-Marquez, Dr. Janice M. Bahr, and Hans H. Stein, Department of Animal Sciences, University of Illinois.*

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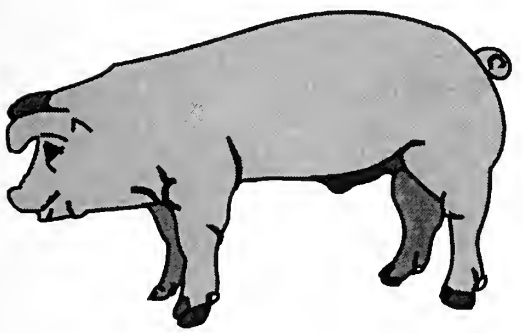

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University of Illinois Swine Research Reports

COLLEGE OF AGRICULTURAL, CONSUMER AND ENVIRONMENTAL SCIENCES

Department of Animal Sciences

THE DEPARTMENT OF ANIMAL SCIENCES

Dennis R. Campion, Head

For more than 125 years, the University of Illinois has been conducting studies on the handling of swine and their products. The science and technology represented in this annual Swine Report is a testimonial to the commitment and dedication of the many current faculty and staff in the Department of Animal Sciences to the improvement in the competitiveness of Illinois' pork producers. We trust that many of the results of the studies reported herein will be of direct benefit to you.

I would like to take this opportunity to give special recognition to several key university extension personnel who were recently honored for their special efforts in swine extension. They are Gilbert Hollis, Extension Swine Specialist and Ed Ballard, Extension Educator located at Effingham. Gilbert received the 1995 Outstanding Extension Specialist Award from the American Society of Animal Science and Ed received the Sustained Excellence Award this year from the Illinois Cooperative Extension Service. He has provided outstanding program leadership for Shelby and Clay counties and for the Effingham Extension Center.

It is our sincere pleasure to be a part of the swine industry of this great state. We appreciate the interest and support that the Illinois pork producers have so generously given us.

Efficacy of Two New Sources of Lysine and Tryptophan[1]

When using ideal protein in feed formulation, calculations reveal that there are limits that must be placed on replacement of soybean meal with crystalline lysine. Thus, if only feed-grade lysine is used, with no consideration given to supplemental sources of threonine, tryptophan and methionine, only 1.5% crude protein (CP) can be replaced with 0.1% (2.5 lb/ton) feed-grade lysine in lower CP corn-soybean meal diets for growing-finishing pigs. To replace more than 1.5% CP, one needs to consider small additions of feed-grade threonine, tryptophan and methionine. At the present time, the cost of feed-grade tryptophan is a limiting factor in removing more than 1.5% CP (i.e., replacing soybean meal with corn + crystalline amino acids.

In a continuing effort to provide flexibility in commercial feed preparation, the corporations producing feed-grade amino acids have come up with two new products. Archer Daniels Midland Corp. (ADM) is now producing a lysine-tryptophan blend, which is a dry product containing guaranteed levels of 15% L-tryptophan and 56% L-lysine. Orson in France is producing a liquid L-lysine product that the company sells as 50% L-lysine activity.

When new products emerge, it is imperative that biological research be undertaken to ascertain the bioavailable levels of the nutrient in question contained in the product being sold. One could think of this relative to amino acids, for example, as the percentage of lysine in these two products, or the percentage of tryptophan in the new lysine-tryptophan blend (Tryptosine®), that is utilizable for growth by the animal-relative to pure crystalline L-lysine and L-tryptophan. Generally, laboratory animals are used for such evaluation, and our research at Illinois has demonstrated that young chicks are excellent predictors of what would happen relative to biopotency in pigs.

Illinois Research

With Tryptosine®, we titrated graded levels of Tryptosine® in diets that were frankly and singly deficient in either tryptophan or lysine. The tryptophan and lysine activity for chick growth was compared with the tryptophan and lysine activity in existing standard sources of these amino acids, i.e., ADM feed-grade tryptophan and ADM feed-grade lysine. Previous Illinois research had confirmed that ADM feed-grade tryptophan and ADM feed-grade lysine contained 98.5% tryptophan bioactivity and 78.8% lysine bioactivity, respectively.

Our dose titration work with Tryptosine® indicated that the guaranteed tryptophan bioactivity of 15% is correct, and the guaranteed lysine bioactivity of 56% is also correct. The data shown in

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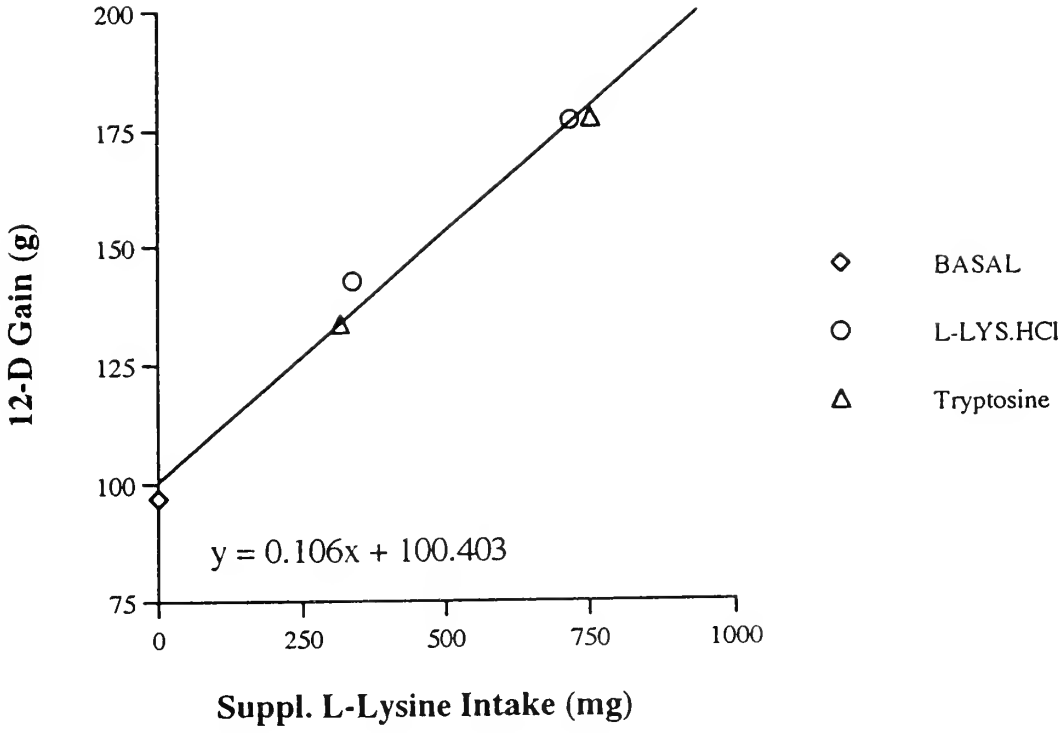
[1]*Prepared by Dr. David H. Baker, Dr. Sergio Fernandez, Hardy M. Edwards III and Douglas M. Webel, Department of Animal Sciences, University of Illinois.*

Figure 1, however, were based on actual lysine or tryptophan intake from feed-grade L-lysine•HCl (78.8% L-lysine), tryptophan (98.5% L-tryptophan) and Tryptosine® (analyzed to contain 56.3% lysine and 16.1% tryptophan). With Orson liquid lysine, graded doses of this product were supplemented and compared to graded doses of ADM feed-grade lysine for young chicks fed a lysine-deficient corn-feathermeal-soybean meal diet. Multiple linear regression slope-ratio assessment of efficacy indicated a lysine potentency in the liquid lysine product of 49.5%, which was not significantly different from the company label of 50% lysine activity.

Implications

Tryptosine® will likely be priced in a manner wherein the cost per unit of L-tryptophan will be similar to the cost per unit of L-tryptophan in existing L-tryptophan products. The bonus will come in the extra lysine contained in the product. Because the ratio of L-lysine:L-tryptophan in Tryptosine® is 3.73:1, additional supplemental lysine will almost always be necessary in low-protein swine diets that are fortified with Tryptosine®.

Liquid lysine appears to be a good product that will allow feed manufacturers who wish to add lysine in liquid form the flexibility of doing so.



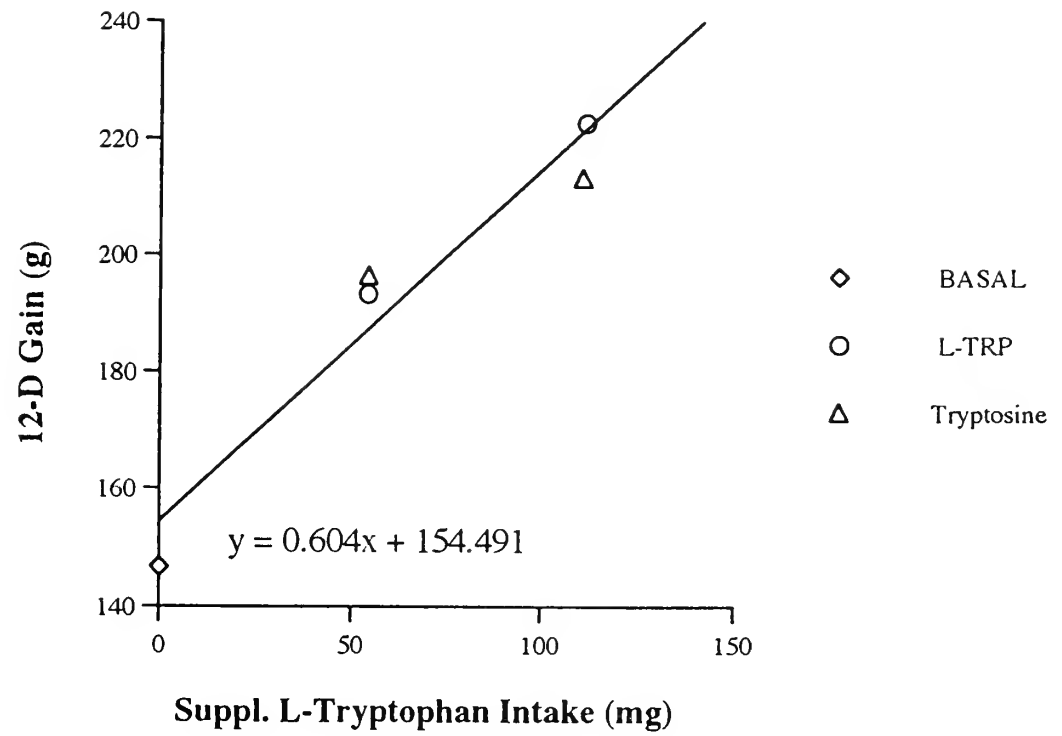


FIGURE 1. Weight gain responses to supplemental lysine or tryptophan provided as either feed-grade lysine or tryptophan or as Tryptosine®. Data points are mean values of triplicate groups of three male chicks during a 12-d feeding period.

Phytase and 1α-Hydroxylated Vitamin D_3 Compounds for Use in Animal Nutrition

The efficacy of microbial phytase, 1,25 dihydroxycholecalciferol (1,25-$(OH)_2D_3$ and 1α-OH cholecalciferol (1α-OH D_3) in releasing phosphorus (P), calcium (Ca) and trace elements from phytate complexes present in corn-soybean meal diets is now well established in chickens and turkeys (Nelson et al., 1971; Edwards, 1975; Perney et al., 1993; Roberson and Edwards, 1994; Simons et al., 1990; Biehl et al., 1995). Current phytase products, however, are heat labile, such that application of heat from pelleting or extrusion processes would materially reduce the mineral-releasing efficacy of the phytase enzyme. 1α-OH D_3 is heat stabile, and it should represent a future cost-effective means of improving utilization of P and other minerals in feed processing applications involving heat. Moreover, 1α-OH D_3 produces an additive response when provided in the diet along with phytase (Table 1). Our recent results with 1α-OH D_3 suggest that a dose of 10 to 15 μg/kg is just as efficacious as 20 μg/kg for chicks fed P-deficient diets.

Our preliminary results with pigs has indicated that phytase is just as effective in releasing P as is the case in chickens (Table 2). 1α-OH D_3, however, at a dose level of 20 μg/kg, seems to be much less efficacious in pigs than in chickens. Future pig studies will explore doses that are both higher and lower than 20 μg/kg. With phytase, work from Cromwells' laboratory (Cromwell et al., 1993) is representative of several pig studies showing P-releasing efficacy from adding up to 1000 units of phytase per kg of diet. Clearly, both phytase and 1α-OH D_3, alone or in combination, offer potential for reducing feed costs (less need for supplemental inorganic P and other minerals in diets) while at the same time reducing P in excreta. Phosphorus is a known pollutant whose level in excreta from animals and humans is of great concern.

Phytase and Amino Acid Utilization

There are scattered reports on the effectiveness of phytase for improving protein and amino acid digestibility. Some of these studies show positive results, some show negative or neutral results, and some are merely suggestive of positive responses.

Our approach was to use young chicks, first, and to then follow up any potential leads with pig studies. Although digestibility assessment will be done, we felt that a clear-cut means of evaluating phytase efficacy would involve designing diets that were frankly deficient in one or more amino acids (lysine, methionine, threonine and/or valine in our chick studies) and ascertaining if supplemental phytase would produce growth or feed efficiency responses in chicks fed these deficient diets. Thus, the diets were designed to be deficient in one or more amino acids, but were

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[1]*Prepared by Dr. David H. Baker and Robert R. Biehl, Department of Animal Sciences, University of Illinois.*

otherwise adequate in all other essential nutrients, including Ca and P. If, indeed, phytase is improving protein digestibility and/or amino acid absorption efficiency, it should improve growth performance in animals fed amino acid-deficient proteins.

Our first chick study employed a corn-peanut meal diet that, without supplementation, is first limiting in lysine, second limiting in methionine, and third limiting in threonine (Table 2). With all three amino acids limiting (lysine first limiting), with methionine and threonine limiting (methionine most limiting), or with threonine limiting, phytase supplementation at 600 or 1200 units/kg did not elicit a gain or feed efficiency response. This provides what we consider to be strong evidence that phytase does not improve the digestibility of protein in peanut meal.

With a soybean meal basal diet, 1200 units/kg of phytase elicited a feed efficiency but not a gain response in chicks fed amino acid-deficient diets (Table 3). A similar response was not observed in chicks fed the amino acid adequate diet (Diet 4 vs Diet 8). This suggests that phytase may be having a small but significant positive effect in improving the utilization of methionine, threonine, lysine and valine in the protein of soybean meal. The phytate contained in soybeans is located in the protein bodies (Erdman, 1979) so there may be a theoretical basis for expecting a phytase response in animals fed this oilseed. Peanut meal is as rich in phytate as soybean meal, but the phytate is contained in crystaloids or globoids located in the protein body membranes (Erdman, 1979).

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Table 1. Efficacy of 1α-hydroxycholecalciferol (1α-OH D_3) with and without phytase for improving phosphorus utilization of chicks[1]

		Tibia data		
	Weight gain[3] (g)	Weight (mg)	Ash (%)	Ash (mg)
1. None	195[c]	634[c]	29.1[c]	185[c]
2. .10% P	239[a,b]	801[b]	38.7[b]	310[b]
3. 1200 U phytase[3]	245[a,b]	795[b]	38.5[b]	306[b]
4. 20 μg/kg 1α-OH D_3	235[b]	787[b]	40.9[a]	321[b]
5. As 3 + 4	253[a]	897[a]	42.7[a]	384[a]
Pooled SEM	5.5	18	.7	11

[1]Data are means of three pens of four female chicks fed the experimental diets during the period 8 to 20-d posthatching; average initial weight was 88 g.

[2]The basal corn-soybean meal diet contained 12.5 μg/kg cholecalciferol, .63% Ca, .43% P (.10% available P), and 23.9% CP. Phosphorus was supplemented in Diet 2 as KH_2PO_4.

[3]Natuphos® (BASF).

[a-c]Means within columns bearing different superscript letters are significantly different ($P < .05$).

Table 2. Efficacy of phytase and 1α-hydroxycholecalciferol for young pigs fed phosphorus deficient corn-soybean meal diets[1]

Diet supplement	Weight gain (g/d)	Gain: feed (g/kg)	Fibula data	
			Ash (%)	Ash (mg)
1. Corn-SBM basal[2]	295[c]	474[b]	33.2[d]	466[c]
2. As 1 + .10% P (KH_2PO_4)	470[b]	595[a]	36.7[b,c]	708[b]
3. As 1 + 1200 U/kg phytase[3]	463[b]	609[a]	38.4[b]	699[b]
4. As 1 20 μg/kg 1α-OH D_3	327[c]	483[b]	34.7[c,d]	482[c]
5. As 3 + 4	466[b]	616[a]	38.8[b]	695[b]
6. As 1 + .30% P + .25% Ca	546[a]	646[a]	44.0[a]	1073[a]
Pooled SEM	17	19	.8	27

[1]Data are means of three pens of three PIC pigs during a 21-d feeding period (33 to 54-d postweaning); average initial weight was 7.6 kg.

[2]The basal diet was a 20% CP corn-soybean meal diet containing .07% available P, .50% Ca, 16.5 μg/kg vitamin D_3 and 1.20% lysine. The diet also contained 3% soybean oil 1.06% $CaCO_3$, 250 g/T ASP -250, 250 mg Cu/kg from $CuSO_4 \cdot 5H_2O$, and adequate fortification with all trace minerals and vitamins; no inorganic P was present in the diet.

[3]Natuphos® (BASF).

[a-c]Means within columns bearing different superscript letters are significantly different ($P < .05$).

Table 3. Efficacy of phytase for chicks fed peanut meal diets deficient in lysine, methionine and/or threonine

Amino acid(s) deficient[2]	Weight gain (g)	Gain:feed (g/kg)
1. Lys, Met, Thr	142[f]	458[f]
2. Met, Thr	167[e]	478[d,e]
3. Thr	247[b,c]	598[c]
4. None	261[a,b]	670[b]
5. As 1 + 600 U Phytase[3]	135[f]	436[g]
6. As 2 + 600 U Phytase[3]	181[e]	488[d]
7. As 3 + 600 U Phytase[3]	246[b,c]	610[c]
8. As 4 + 600 U Phytase[3]	270[a]	684[a,b]
9. As 1 + 1200 Phytase[3]	144[f]	463[e,f]
10. As 2 + 1200 U Phytase[3]	172[e]	482[d]
11. As 3 + 1200 U Phytase[3]	230[d]	594[c]
12. As 4 + 1200 U Phytase[3]	270[a]	690[a]
Pooled SEM	5.1	6.3

[1]Data represent means of quadruplicate groups of four female New Hampshire x Columbian chicks during the period 8 to 21-d posthatching; average initial weight was 82 g.

[2]The basal diet from which lysine, methionine and/or threonine was deleted was a 23% CP corn-peanut meal diet that met or exceeded NRC (1994) requirements for Ca, P and vitamin D_3. Without lysine, methionine or threonine fortification, it contained, by analysis, .69% lysine, .60% SAA (methionine + cystine) and .61% threonine. It was fortified with .715% L-Lys•HCl, .365% DL-Met and .23% L-Thr, and these, therefore, were the levels of these amino acids that were added (or deleted) to achieve the treatment diets.

[3]Natuphos® (BASF).

[a-g]Means within columns bearing different superscripts letters differ ($P < .05$).

Table 4. Efficacy of phytase for chicks fed soybean meal diets deficient in methionine, threonine, lysine and/or valine

Diet	Weight gain (g)	Gain:feed (g/kg)
1. SBM basal (B)[2]	86.5	329
2. As 1 + .20% DL-Met	166.8	476
3. As 2 + .12% L-Thr	175.4	489
4. As 3 + .12% L-Lys•HCl + .10% L-Val	197.6	541
5. As 1 + 1200 U/kg Phytase[3]	91.8	342
6. As 2 + 1200 U/kg Phytase[3]	167.4	492
7. As 3 + 1200 U/kg Phytase[3]	168.9	504
8. As 4 + 1200 U/kg Phytase[3]	189.3	532
Pooled SEM[4]	5.1	5.7

[1]Data represent means of triplicate groups of four male New Hampshire x Columbian chicks during the period 10 to 20-d posthatching; average initial weight was 124 g.

[2]The basal diet contained 21.05% dehulled soybean meal, 44% cornstarch, 22% dextrose and 5% soybean oil. It was fortified to adequacy with all essential minerals and vitamins, and also contained supplemental histidine, arginine and tryptophan; 2.55% of a 2:1 mixture of glutamic acid and glycine was added to bring the total dietary crude protein to 12%.

[3]Natuphos® (BASF).

[4]Statistical comparisons: 1 and 5 vs 2 and 6 ($P < .01$) for both gain and gain:feed; 2 and 6 vs 3 and 7 ($P < .05$) for gain:feed; 3 and 7 vs. 4 and 8 ($P < .01$) for both gain and gain:feed; 1, 2 and 3 vs. 5, 6 and 7 ($P < .01$) for gain:feed; 4 vs 8 not significant ($P > .10$) for both gain and gain:feed.

Feed Intake Pattern of Group Housed Growing Pigs Monitored by a Computerized Feed Intake System

Background

The feed intake of pigs is an important factor in determining performance levels and has a major impact on nutritional programs. An estimate of feed intake is an essential pre-requisite to establishing diet specifications and is, therefore, central to accurate practical diet formulation. However, there are problems associated with obtaining detailed and accurate measures of feed intake, particularly for animals in groups. Most research facilities are designed for group sizes that are much smaller than used in commercial practice. In addition, each group produces a single estimate of group feed intake and, therefore, relatively large numbers of groups and of animals are needed to obtain accurate feed intake data. Recently, however, equipment has been developed that allows the measurement of the feed intake of individual pigs when housed in groups. This equipment was originally designed for group performance testing pigs in genetic improvement programs but provides a novel mechanism for studying feed intake behavior of individual animals in groups. In addition to data on individual feed intake levels, such equipment also records feeding patterns in terms of the timing and duration of each visit to the feeder and individual meal sizes. This development, therefore, has the potential to provide researchers with a method to obtain detailed individual animal feed intake behavior data as well as absolute intake levels in group situations.

The study reported in this paper was carried out to investigate feed intake levels, growth performance, and feeding patterns of boars, barrows and gilts when fed diets with varying lysine and protein levels.

Materials and Methods

The study was designed as a three by four factorial with the treatments comprising three sexes (barrows, entire males and gilts) and four diets. The dietary treatments had 4 different crude protein levels which ranged from 14 to 19 % between 30 to 55 kg live weight, from 13 to 17% for the remainder of the study. Eight pens of pigs were randomly allocated to dietary treatment to provide two pens on each diet. The pigs used were the progeny of PIC Line 26 males mated to Camborough females. A total 120 animals comprising equal numbers of barrows, entire males, and gilts were selected and randomly allocated to 8 pens to produce test groups of 15 pigs per pen and equal numbers of each sex within each pen. The test started when mean pen live weight was 27 $\pm$ 3.7 kg and ended after a 10 week period at which stage mean pig weights were 81.5 $\pm$ 9.2 kg. The study period was split into two phases, with the first phase from start of test to 55 kg live weight and the second phase from 55 kg the end of

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[1] *Prepared by Young Hyun, Michael Ellis and Floyd K. McKeith, Department of Animal Sciences, University of Illinois, Urbana, IL 61801*

the study. The space allowance was constant throughout the study at 0.8 m^2 per pig. The accommodation had continuous lighting for 24 hrs each day and water was available at all times. Feed intake was recorded using Feed Intake Recording Equipment (F.I.R.E., Hunday Electronics Ltd, Newcastle Upon Tyne, England). Each of the eight pens was equipped with a feed station which comprised a feed trough connected to a load cell and receiving equipment to pick up radio signals from the ear tag transponder carried by the animals. Data on daily feed intake traits for individual animals were used to estimate mean values for daily feed intake (kg), number of feeder visits per day, number of meals per day, feed intake per visit (g), feed intake per meal (g), feeder occupation time per visit(min), feed occupation time per meal (min), total feeder occupation time per pig per day (min), and feed consumption rate (g/min).

Results and Discussion

Sex and Diet Effects. Sex and diet effects on growth performance and feed intake traits are presented in Table 1. Average daily gain was higher for boars and barrows compared to gilts, and gain:feed ratio which was higher in boars than in the other two sexes. There was little difference between the sexes for feed intake level or feeding behavior. Growth rates and feed intake were higher for diet 3 and 4, with the higher intakes resulting from greater feed intake per visit due to increased feeder occupation time at each visit rather than any increase in feeder visits per day or consumption rates. However, dietary effects on feeding behavior traits were relatively small and of uncertain practical relevance.

Feeding Behavior. The data suggest that pigs visited the feeder on average around 12 times per day and approximately half of these were classed as meals. In the current study, feed intake per visit, feeder occupation time per visit and total feeder occupation time per day averaged approximately 150 g, 6.6 min. and 76 minutes respectively. Feed intake per meal and feeder occupation time per meal averaged about 262 g and 11.0 minutes. Feed consumption rates were approximately 24 g/min.

Correlations between Growth Performance and Feed Intake Traits. Correlations between growth performance and feed intake traits are summarized in Table 2. Correlations between average daily gain and gain:feed ratio respectively and number of feeder visits, feed intake per visit, feeder occupation time and feed consumption rate were generally low. Increases in daily intakes were largely a consequence of greater meal sizes resulting from larger feed intake per visit and longer feeder occupation time rather than from any increase in the number of visits to feeder per day.

Diurnal Feeding Patterns. A strong diurnal pattern in feed intake behavior was observed as illustrated in Figure 1 where patterns for the 3 sexes are presented. There was one peak in feeding activity which was between approximately 0700 and 1900 hrs. Feeder visits were lowest during the nighttime period (ie. between 2000 and 0500 hrs), showed a rapid increase from 0600 to 0800 hrs, peaked at 0800 and 0900 hrs, and declined slowly from 1000 to 2000 hrs. Distributions of feed intake, feeder occupation time, and feed consumption rate by time of a day showed similar trends. However, feeder occupation time per visit and feed intake per

visit showed an inverse pattern to the number of feeder visits. Thus, the length of visits decreased and consumption rates increased at times of the day when competition for the feeder was greatest. Feed consumption rate has been shown to increase with competition and is a mechanism for maintaining feed intake levels in group situations when competition for feed is high.

Generally, the 24 hour patterns in boars, castrates and gilts were similar. There was a suggestion that boars consumed a greater proportion of their total daily feed during the period of peak feeder activity and that this was mainly associated with longer feeder occupation times compared to barrows and gilts. This data suggests that entire males were move successful at achieving feeder access when competition was greatest. Feeding patterns for barrows and gilts were generally similar with the exception that feed consumption rates tended to be higher for barrows.

Changes in Feed Intake Pattern with Weight. The regressions for daily feed intake and feed intake pattern on body weight are summarized in Figure 2. As anticipated, daily feed intake showed a linear increase over the weight range studied. There was a curvilinear regression for number of meals, where changes with weight were small, ranging 6 to 7 meals per day. As a consequence of these changes in feed intake, and meal and visiting frequency, and feed intake per meal showed little change between 25 and 50 kg but increased thereafter. Feeder occupation time per meal and per day showed steady declines with weight whereas feed consumption rates increased dramatically from less than 20 g/min at around 25 kg to in excess of 30 g/min at 80 kg. Meal duration showed little change with age. These data suggest that increases in weight are associated with little change in feeder visits per mealing frequency, a decrease in the time spent feeding, and an increase in both meal size and consumption rate.

Implication

These results suggest small differences between entire males, barrows and gilts and a relatively small effect of dietary protein levels on daily feed intake patterns. Feeder occupation time decreased and feed consumption rates increased at times of the day when competition for access to the feeder was highest. Increases in feed intake with weight were largely due to increased feed consumption rates.

Acknowledgment

The authors would like to thank the Pig Improvement Company Inc., Franklin, KY and Osborne Industries Inc., Osborne, KS for assistance with this study.

Table 1. *Sex and diet effects on growth, feed efficiency, and feed intake traits*

Traits	Sex					Protein level (%)					
	Barrow	Boar	Gilt	Av.S.	Sig.[1]	14/13	16/14	17/16	19/17	Av.S.	Sig.
Initial weight(kg)	27.3	26.9	27.0	.64	ns	26.8	27.3	26.7	27.4	.74	ns
Final weight(kg)	82.9	82.5	79.0	1.36	ns	76.2 ^{a}	81.2 ^{ab}	84.4 ^{b}	84.1 ^{b}	1.58	**
Average daily gain (g)	795 ^{a}	795 ^{a}	743 ^{b}	14.6	*	706 ^{a}	770 ^{b}	824 ^{c}	810 ^{bc}	17.9	**
Gain:Feed	.45 ^{ab}	.47 ^{a}	.44 ^{b}	.008	*	.43	.45	.46	.46	.009	ns
Daily feed intake (kg)	1.79	1.70	1.69	.033	ns	1.64 ^{a}	1.70 ^{b}	1.79 ^{c}	1.78 ^{c}	.038	*
Number of visits per day	12.6	11.6	11.9	.49	ns	12.8	12.7	11.4	11.2	.57	ns
Number of meals per day	7.4 ^{a}	7.0 ^{b}	7.0 ^{b}	.10	**	7.5 ^{a}	7.4 ^{a}	6.8 ^{b}	6.8 ^{b}	.12	**
Feed intake per visit	150	155	152	6.9	ns	134 ^{a}	141 ^{a}	168 ^{b}	169 ^{b}	8.9	**
Feed intake per meal	261	264	261	4.8	ns	230	245	290	283	5.6	**
Feeder occupation time per visit (min/pig)	6.5	6.6	6.6	.27	ns	6.2 ^{a}	6.0 ^{a}	7.1 ^{b}	7.1 ^{b}	.31	**
Feeder occupation time per meal (min/pig)	10.8	11.0	11.1	.23	ns	10.0	10.1	12.0	11.8	.27	**
Total feeder occupancy time per day (min)	78.1	73.4	75.8	2.61	ns	75.6	73.7	76.9	76.9	3.01	ns
Feed consumption rate (g/min)	23.6	24.1	23.4	.85	ns	22.5	24.2	23.6	24.3	.98	ns

[1] ns, *, ** : not significant, $p < .05$, $p < .01$, resp.
Means in the same row within treatment with differing superscripts are different.

Table 2. *Correlations between growth performance and feed intake traits*

Traits	BW	ADG	DFI	FE	NFV	NMD	FIV	FIM	FOV	FOM	FOD	CR
Body weight	-											
Average daily gain	.70	-										
Daily feed intake (DFI)	.58	.59	-									
Gain:Feed (FE)	.19	.53	-.34	-								
Feeder visit per day	-.02	-.13	-.28	.14 [1]	-							
No. of meal per day (NMD)	.06 [1]	-.08 [1]	-.24	.16 [1]	.92	-						
Feed intake per visit (FIV)	.29	.38	.70	-.29	-.84	-.80	-					
Feed intake per meal (FIM)	.30	.39	.73	-.28	-.73	-.79	.95	-				
Feeder occupation time per visit (FOV)	-.01 [1]	.11 [1]	.42	-.31	-.61	-.59	.68	.63	-			
Feeder occupation time per meal (FOM)	-.01 [1]	.11 [1]	.42	-.31	-.50	-.65	.62	.66	.96	-		
Feeder occupation time per day (FOD)	-.01 [1]	.02 [1]	.25	-.24	.17 [1]	.16 [1]	.01 [1]	.04 [1]	.64	.68	-	
Feed consumption rate (CR)	.35	.32	.31	.06 [1]	-.26	-.22	.34	.32	-.43	-.46	-.79	-

[1] not significant, $P > .05$.

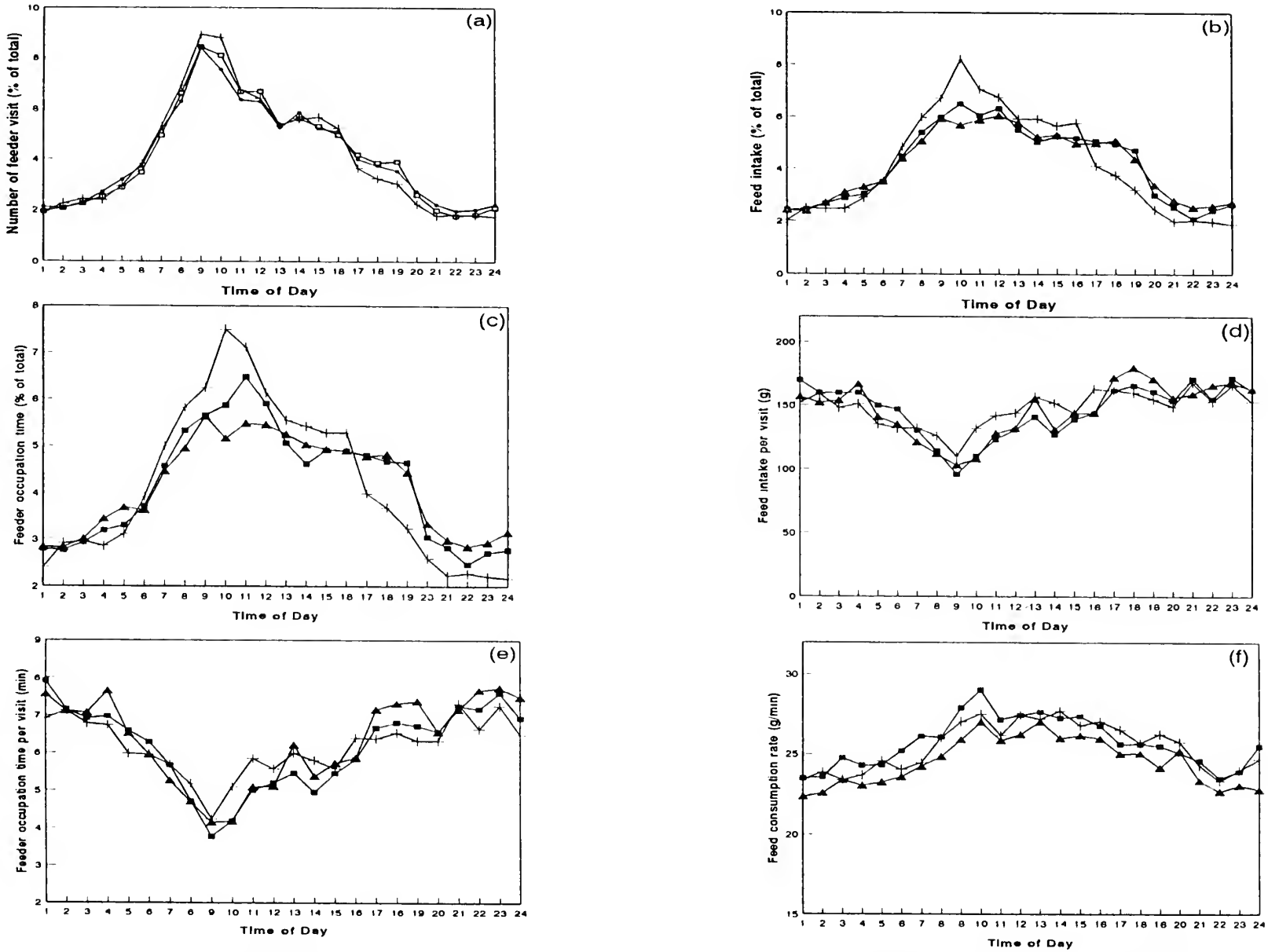

Figure 1. Distribution of feed intake traits of boar (+), barrow (■) and gilt (►) by time of day during the test period; (a) feeder visit, % of total frequency; (b) feed intake, % of total feed intake; (c) feeder occupation time, % of total feeder occupation time; (d)feed intake per visit, g; (e)feeder occupation time per visit, min; (f)feed consumption rate, g/min.

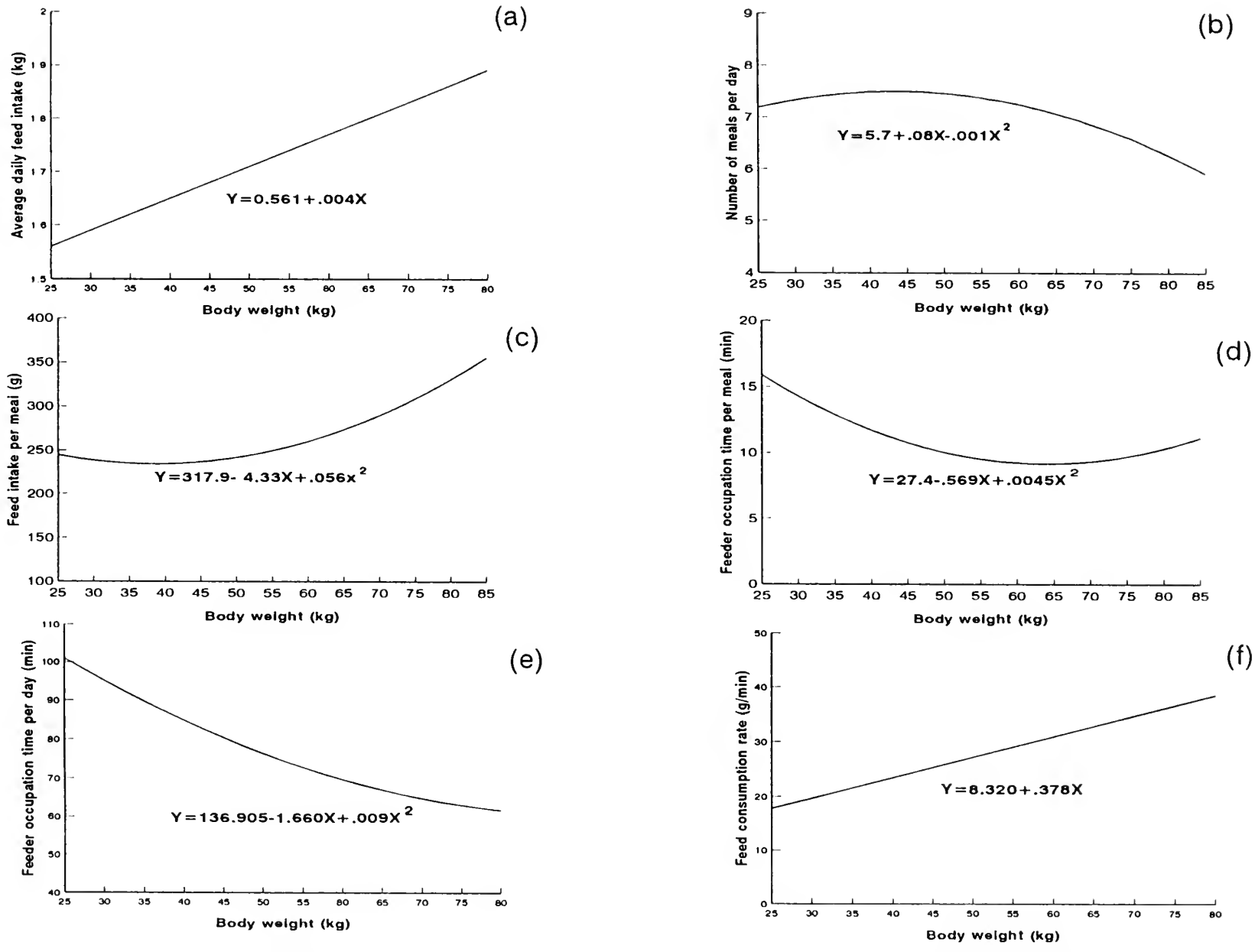

Figure 2. Regression analysis of feed intake traits on body weight; (a) daily feed intake; (b) no of meals per day; (c) feed intake per meal; (d)feeder occupation time per meal; (e) feeder occupation time per day; (f) feed consumption rate per pig.

The Growth Performance, Carcass Characteristics and Meat Quality of Halothane Carrier and Negative Pigs[1]

Introduction

Although there has been considerable recent discussion regarding the Halothane gene, this is not a new issue. Interest in this gene dates from over 30 years ago and there has been a large amount of research carried out investigating its effects. So why the renewed interest? A number of factors have been responsible for this. Arguably, the major cause of the renewed interest is the increased premia being paid for lean carcasses by the packing industry. This has led producers to look for rapid ways to increase carcass lean content and the Halothane gene has the potential to achieve this. In addition, a DNA test was developed in Canada in the early 1990s which, for the first time, allowed halothane carrier and negative pigs to be distinguished and, therefore, the frequency of the halothane gene in a population to be manipulated relatively easily. Parallel to these developments has been the increased interest in meat quality and particularly in the pale soft exudative (PSE) condition. This condition results in significant economic loss to the industry and meat sector and halothane reactors are known to have a higher incidence of PSE meat than negative pigs. However, the meat quality and carcass composition of halothane carrier pigs relative to negative animals is less clearly established. Recent evidence from Canadian studies has suggested that the performance of carriers relative to negatives or reactors may vary with slaughter weight. These studies showed that at lighter slaughter weights (below 100 kg live weight) carriers had similar carcass lean contents and PSE incidence to negatives and that both genotypes had lower lean percentage and PSE incidence than Halothane reactors. In contrast, at heavier weights (ie. up to 130 kg live weight) carriers were similar to reactors, having significantly higher lean contents and PSE incidence than negative pigs. Given that slaughter weights for pigs are increasing in the US, there was a need for a re-evaluation of the relative performance of carrier and negative pigs from modern genotypes, taken to heavier slaughter weights. This study was, therefore, carried out to investigate the on-farm performance, carcass and meat quality characteristics of Halothane carrier and negative pigs slaughtered at a range of weights between 110 and 140kg.

Methods

The study was conducted at the Swine Research Center at the University of Illinois. Halothane carrier and negative animals were produced in the same litter by mating carrier boars to negative sows thus allowing the effects of the gene to be assessed within a common genetic background. Halothanegenotype was established using the HAL-1843® DNA test. A total of 144 pigs were grown from 40 kg live weight, in conventional housing and using standard diets, and slaughtered at either 110, 125 or 140kg. Following slaughter at the Meat Laboratory, carcass composition and cutting and curing yields were obtained, and raw and cooked meat quality was evaluated on the loin muscle. Eating quality was assessed on samples of loin muscle that had been cooked under controlled conditions using a trained taste panel.

[1]*Prepared by Linda.M. Leach*, Mike Ellis, Doug S. Sutton, Floyd K.McKeith, and Eldon R. Wilson*, Department of Animal Sciences, University of Illinois and *Pig Improvement Company, Inc., Franklin, KY*

Results

The growth and carcass characteristics of the two genotypes are summarized in Table 1. Growth rates of carriers and negatives were similar, but carriers had higher gain:feed ratios, carcass weights, and dressing percentages compared to negatives. At slaughter weights of approximately 120 kg, these differences would result in a saving of 21 kg of feed and an increase in carcass weight of 1.2 kg for carriers compared to negatives. There are obvious financial benefits to producer from producing carrier animals. Backfat thickness and loin eye measurements were not different between the genotypes (Table 1) but carriers gave higher lean-cut yields and fat-free lean contents which would be of economic advantage to the packing industry. Belly yields were similar for the two genotypes, however, ham curing yields were 2.1 percentage units lower for carriers (Table 1).

Meat quality measurements taken on the loin showed lower values for carriers for pH at 45 minute and 24 hour post mortem, and for color, firmness and marbling scores, but higher values for Minolta L* color and drip loss. These results, therefore, suggest a higher incidence of PSE for carriers compared to negatives. Estimates of the frequency of PSE carcasses in this study based on color scores and drip loss values suggest it is of the order of approximately 7 % for carriers compared to 0 % for negative animals. Despite this difference, the eating quality of meat from the two genotypes was similar (Table 2).

In this study, there was no evidence that the differences between the two genotypes changed across the slaughter weights used (ie. 110 to 140 kg) and, therefore, the relative advantages and disadvantages of carriers compared to negatives will be maintained to weights above those currently used for the majority of slaughter pigs in the US industry.

Conclusions

1. This study identified advantages to the producer for Halothane carriers compared to negatives in terms of greater feed efficiency and higher carcass yields. These advantages would result in lower production costs and higher carcass values.
2. The higher carcass lean contents for carriers would be of economic advantage to the meat sector. However, the higher PSE incidence and lower ham curing yields for carriers will result in some economic loss.
3. The eating quality of loin chops was similar for the carriers and negatives.
4. Differences between the two halothane genotypes were similar across the weights studied (ie. between 110 and 140 kg) suggesting that the relative advantages and disadvantages of carriers will be maintained across the range of slaughter weights currently required by the majority of slaughter plants in the US.

Acknowledgement
The authors are grateful to the Pig Improvement Company, Inc., Franklin, KY for supplying the genotypes and financial support.

[1] The HAL-1843® trademark is licensed from the Innovations Foundation, Toronto, Canada, owner of the trademark.

Table 1. Growth and carcass characteristics of Halothane carrier and negative pigs

Genotype				
Variable	Carrier	Negative	s.e.m.	Sig.[a]
Average daily gain, g	974	964	16.9	NS
Gain:Feed	.36	.33	.005	**
Final live weight, kg	121.8	121.5	.49	NS
Cold carcass weight, kg	91.6	90.4	.46	*
Dressing percentage	75.3	74.4	.29	***
Tenth rib measurements, cm:				
Fat depth, 6.5cm off midline	2.4	2.6	.12	NS
Loin eye depth	5.9	5.6	.10	NS
Loin eye area, cm^2	42.9	41.5	1.20	NS
Side lean-cut yield:				
Weight, kg	19.8	19.2	.24	**
Percentage	44.1	43.1	.49	*
Side fat-free lean content:				
Weight, kg	24.7	23.9	.35	*
Percentage	55.1	53.8	.70	NS
Curing Yields, %:				
Belly	100.4	100.6	.52	NS
Ham	100.8	102.9	.62	**

[a]NS, *, **, *** = not significant, P<.05, P<.01, P<.001, respectively.

Table 2. Meat quality measurements taken on the loin muscle for Halothane carrier and negative pigs

Genotype				
Variable	Carrier	Negative	s.e.m.	Sig.[a]
45 minute, pH	6.4	6.6	.05	***
24hour, pH	5.6	5.7	.03	**
Color[b]	2.2	2.7	.12	***
Firmness[b]	2.2	2.9	.12	***
Marbling[b]	1.2	1.7	.12	***
Minolta L*color[c]	45.7	42.0	1.03	***
Drip loss, %	5.2	3.4	.43	***
Warner-Bratzler shear force, kg	3.4	3.4	.17	NS
Cooking loss, %	27.1	25.6	.89	NS
Juiciness[d]	7.3	7.6	.27	NS
Tenderness[d]	9.1	9.2	.30	NS
Off-flavor[d]	14.3	14.4	.07	NS
Water content, %	73.7	73.4	.17	NS
Fat content, %	2.0	2.3	.20	NS

[a]NS, *, **, *** = not significant, $P < .05$, $P < .01$, $P < .001$, respectively.
[b]Subjective score from 1 = extremely pale, soft, and devoid of marbling to 5 = extremely dark, firm, and moderate or abundant marbling.
[c]Higher values = paler color.
[d]Subjective score from 0 = extremely dry, tough and intense off-flavor to 15 = extremely moist, tender, and no off-flavor.

EVIDENCE OF APOPTOSIS (*) IN OVARIAN CELLS OF SOWS FED LOW ENERGY DIET DURING LACTATION

INTRODUCTION

Sows receiving a low energy diet or ingesting a low quantity of feed experience massive losses of weight during lactation. In general these animals do not return to estrus after weaning as promptly as well fed animals (King & Williams, 1984). The problem is of great practical importance because the lactating sow has a high energy requirement due to milk production. However, in most cases the appetite and feed intake are not adequate to support milk production and meet the requirements of the piglets , so mobilization of body tissue occurs (Reese, 1983). Moreover the incidence of anestrus is particularly high in primiparous sows, that constitute between 20 and 40% of the breeding females of the herd; this problem has a major economical and practical impact on swine production.

Although many factors affect reproduction in pig, there is an endocrine basis for this problem of post-lactactional anestrus (Armstrong & Britt, 1987). In previous research we measured lower concentrations of insulin-like growth factors I and II in serum of sows fed a low energy diet during lactation (Rodriguez Marquez et al. 1995a). Moreover, estrogen production by the ovaries of these sows was low as a result of a nutritional insufficiency during lactation (Rodriguez-Marquez et al., 1995). The main cause for low estrogen production was attributed to a reduced activity of several steroidogenic enzymes namely P450c17 (that catalyzes the reaction of progesterone to androgens) and P450aromatase (that catalyzes the reaction of androgens into estrogens) (Rodriguez-Marquez, 1995b). A probable cause for the lack of activity of these essential steroidogenic enzymes could be due to apoptosis (programmed cell death) of ovarian cells which contain these enzymes.

OBJECTIVES

The objective of our studies was to determine if apoptosis is present in ovaries of sows fed low energy diet during lactation. To investigate the effect of level of energy intake on the incidence of apoptosis, six gilts were divided into two groups depending on lactation energy intake. Two diets were prepared where the only limiting factor was energy. The control group was fed 17.0 Mcal/day ME and the low energy group 8.5 Mcal/day ME. Four days after weaning the sows were sacrificed and their ovaries were taken for analysis. Ovarian tissues were fixed with 10% neutral buffered formalin, then embedded in Paraplast after dehydratation with increasing concentrations of ethanol.

(*) Programmed death of cell.

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Paraffin sections (5 micrometers) were prepared and processed to detect apoptosis in follicular cells with an immunocytochemistry kit, ApopTagPlus kit (Oncor). The ApopTag Plus kit detects apoptotic cells by direct immuno-peroxidase detection of dioxigenin-labeled genomic DNA in thin sections of fixed tissue.

RESULTS

Apoptosis, programmed cell death, is considered to be an active, regulated response by cells to a specific stimulus. It is an active form of cell death derived from a normal, physiological, process; ultrastructurally the earliest changes of apoptosis include the loss of cells junctions and other specialized plasma membrane structures such as microvilli. At the same time the cytoplasm condenses and nuclear chromatin coalesces into one or several large masses. As the process continues the nucleus breaks into several fragments. As the process occurs, cells stop functioning. In the case of the ovarian cells, production of steroids specifically estrogens essential for reproduction is terminated.

Granulosa cells of ovarian follicles in sows fed a low energy diet during lactation showed apoptosis. No sign of apoptosis was observed in sows fed control diet. One of the causes for low estrogen production by the ovaries of sows fed low energy diet during lactation may be the high occurrence of apoptosis in the granulosa cells, which are the site of estrogen production. The development of apoptosis in ovaries of sows which experienced massive loss of weight during lactation, may be one the principal causes for the occurrence of anestrus in these sows. As a result the sows may need more time to replace apoptotic cells which may explain the delay in the return to estrus of sows who do not consume sufficient energy during lactation.

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Production of Transgenic Pigs with Altered Milk to Improve Piglet Growth, Health and Survivability

Abstract[1]

Transgenic pigs containing gene constructs that are designed to improve sow milk have been produced and are continuing to be generated. The initial transgenic pigs contain a gene construct for the milk protein α-lactalbumin. Transgenic mice made using this same gene construct produce more of the milk carbohydrate lactose and their offspring grow 7.5% faster than do normal mice. The transgenic pigs will be examined to see if similar milk and growth characteristics are observed.

Introduction

Milk production and composition of the sow influences all subsequent production aspects of pork production. Low milk production decreases piglet growth rate and results in decreased piglet weaning weight. This decreased weaning weight affects overall pig performance through the nursery, grower and finishing stages and also effects general piglet health. Decreases in weaning weight prolong the weaning to first estrus interval and lower the ovulation rate and subsequent litter size. Lactational efficiency may also ultimately affect sow longevity in the herd, since a number of sows are culled from the herd due to poor lactational performance. Current swine management schemes attempt to maximize the number of piglets born per litter and piglet survival (Hartmann et al., 1984). In order to utilize the larger litter sizes and keep the piglets healthy and alive, maximum production of milk must be obtained. Indeed, the gains that have been made in decreasing neonatal mortality combined with the increased litter sizes from selected high genetic merit sows make milk production one of the most important limiting factors in piglet survivability and growth. In fact, studies indicate that milk production and milk composition of the sow accounts for 44% of the growth weight of the piglets (Lewis et al., 1978).

The potential effect of increasing sow milk production to U.S. pork production is dramatic. Using current milk production values and assuming that a piglet gains ~164 g/day from birth to weaning (Lewis et al., 1978) then increasing milk production 10% would result in an additional $2.46 per litter weaned (Ave. litter size 7.8). When that figure is applied to the 90.2 million pigs produced in

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1991 (USDA statistics) then a 10% gain in milk production would be worth $28.4 million/year in the U.S. due to increased weight gains prior to weaning. This calculation does not take into consideration decreased feed and labor costs associated with rearing pigs that have heavier weaning weights and the additional benefits of more piglets surviving per litter. Therefore, there would be additional savings due to reduced time that pigs are grown prior to market and an increased number of piglets surviving to market weight.

Large increases in average milk production of dairy cattle have been realized over the past several decades because of intense selection for a trait that is easy to objectively measure in dairy cattle, yield of milk. However, despite the importance of milk production for fast growth, health and survivability of the offspring of pigs, negligible increases in milk production have been made in swine. Furthermore, although research has provided insight into the potential role of various growth factors and other bioactive peptides in the development and protection of the neonatal pigs, very few attempts have been made to utilize these benefits in swine production systems. We are attempting to produce a mechanism that can be used to improve milk for the improvement of piglet growth, health and survivability. We are generating transgenic pigs that produce increased levels of certain proteins specifically in milk to accomplish this goal.

Using genetic engineering and transgenic animals it has become possible to modify proteins and then have them secreted into the milk of a transgenic mammal. For example, it has been shown that it is possible to express a wide variety of different proteins in the milk of mice, rabbits, pigs, goats, sheep and cows (Simons et al., 1987; Buehler et al., 1990; Wall et al., 1991; Ebert et al., 1991; Clark et al., 1989; Krimpenfort et al., 1991). Most of this work has been performed using proteins of pharmaceutical interest. In our studies, we have chosen to express proteins in milk of transgenic animals that have the potential to improve the quality of sow milk and be beneficial to the pork industry.

The most common way of making transgenic animals is by microinjection of DNA encoding a gene of interest into the male pronucleus of a fertilized egg. The fertilized eggs are obtained using normal embryo transfer techniques. The genes are injected at the one cell stage of embryo development, and the genes become incorporated into all cells of the individual, including the germ cells, and are thus capable of being transmitted to one-half the offspring of that animal (Bremel et al., 1989).

The genes encoding these foreign proteins are transmitted through normal Mendelian inheritance and the animals produce the proteins only in their milk during lactation. These new genes can be propagated in the swine population by use of embryo transfer and artificial insemination.

Results

Previous work has suggested that the volume of milk produced is directly dependent upon the amount of lactose synthesized. Lactose, the major milk carbohydrate, is synthesized in the Golgi apparatus of mammary secretory cells by the lactose synthase complex. This complex is composed of the mammary specific protein α-lactalbumin and the enzyme β1,4 galactosyltransferase. Because lactose cannot diffuse out of the mammary secretory vesicles, it acts to draw water by osmosis into the vesicle and subsequently into milk. Because of this osmotic function, lactose has been hypothesized as being limiting for milk production. We have produced transgenic mice containing the bovine α-lactalbumin gene (Bleck and Bremel, 1994). These transgenic mice produce higher levels of α-lactalbumin in their mammary gland, have higher activity of the enzyme lactose synthase and appear to produce more lactose in the milk. In addition to the changes in milk, offspring of these mice weigh 7.5% more than normal control mice ten days after birth.

We have generated pigs and are in the process of generating more transgenic pigs that contain the same gene construct as the mice described above. These pigs are currently being bred and propagated to enable studies examining potential changes in the milk and piglet growth to be performed.

A second mechanism by which the alteration of milk composition may benefit the pork industry is through the addition or supplementation of beneficial hormones, growth factors or bioactive factors to the milk through the use of transgenic animals. It has been suggested that bioactive substances in milk possess important functions in the neonate with regard to: regulation of growth, development, and maturation of the gut, immune system and endocrine organs (Grosvenor et al., 1993). The overexpression of a number of these proteins in milk through the use of transgenic animals may improve growth, development and survivability of the developing offspring. Some factors that have been suggested and shown to have important biological functions in the neonate that are obtained through milk include insulin-like growth factor-I, epidermal growth factor, transforming growth factor α and lactoferrin (Grosvenor et al., 1993). In this study we are also testing the bovine α-lactalbumin gene regulatory regions for their usefulness as a mammary expression system for the production of these types of therapeutic proteins in the milk of sows.

Conclusions

Preliminary studies demonstrated that the α-lactalbumin 5' regulatory region is capable of driving high levels of α-lactalbumin expression specifically in mammary tissue of transgenic mice. Furthermore, they indicate that the constructs for α-lactalbumin are expressed at high levels. Therefore we are in a unique position to investigate the importance of α-lactalbumin to the lactose synthase complex, milk production, piglet health and piglet survivability in swine. Also this study will allow us to examine the usefulness of the bovine α-lactalbumin 5' flanking region as a mammary specific expression vector in swine.

The long-term goal of this research will be to produce lines of swine with improved milk yield and composition, causing improved piglet survivability and health. Higher expression of a limiting milk component should result in higher milk production and/or higher concentration of that specific milk component. These improved milk characteristics will have a beneficial effect on the growth, health and development of the piglets.

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The Effects of Micro-Aid on Sow Reproduction

Introduction

The average stillbirth rate of sows in the United States is approximately 0.9 pigs per litter. Published literature suggest that this rate of stillbirths has remained relatively constant for over 50 years despite significant advances in nutrition, genetics, disease control and management. Stillbirth piglets represent an annual loss of over $300 million to the United States swine industry. Previous research at the University of Illinois (Specher, 1974) found approximately 80% of stillbirths occurred in the last third of the birth order. This research strongly supported the theory that insufficient oxygen supply to the fetus during farrowing is associated with over 80% of non-infectious stillbirths. Previous researchers have utilized blood pH, blood lactate and pCO2 as indirect measurements of oxygen insufficiency because of difficulties in direct measurement of blood oxygen values. Rental (1971) found low viability piglets to have significantly lower blood pH and higher pCO2 than normal piglets, indicating oxygen insufficiency was a major cause of low viability at birth. English and Smith (1975) found blood lactate levels at birth to be significantly correlated to pre-weaning mortality, indicating that oxygen insufficiency was a major cause of pre-weaning mortality.

The commercial feed additive MICRO-AID has been should by several researchers to reduce ammonia emissions from livestock manure. Recent research with broilers (Anthony 1994 and Balog 1994) has documented a significant reduction in ascites mortality by feeding MICRO-AID. Ascites is a metabolic syndrome caused by insufficient oxygen supply. The mode of action appears to be related to a reduction in intestinal ammonia and corresponding reductions in mucosal tissue turn over rates and tissue oxygen demand. Previous work at the University of Illinois (Jensen 1982) found that feeding MICRO-AID to lactating sows slightly increased their feed consumption and significantly ($P<0.09$) reduced pre-weaning mortality (39%).

This research was designed to evaluate the effects of feeding MICRO-AID to sows prior to the start of farrowing and to measure its effects on piglet blood oxygen levels at birth, the rate of stillbirths and pre-weaning mortality.

Procedures

A total of 81 multiparous cross-bred females from the university herd were fed a corn-soy lactation diet (Table 1) containing either 0 or 125 ppm of MICRO-AID, upon entering the farrowing room (approximately 5 days prior to farrowing) until weaning at 21 days.

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Table 1. Sow Lactation Diet

Ingredient	%
Corn	84.55
Soybean Meal 48%	13.00
Dicalcium Phosphate	1.25
Limestone	0.75
Trace Mineral Salt	0.35
Vitamin Premix	0.05
CTC-50	0.05
Total	100.00
Calculated Analysis:	
Crude Protein, %	13.74
Lysine, %	0.62
Metabolizable Energy kcal/kg	3332

Sows were allotted to treatment groups based upon parity. Standard university procedures were following in all management and data recording operations. Piglets were considered stillborn if they were either born dead or were found dead at the rear of the sow.

Blood oxygen values were obtained at the time of birth for 483 piglets representing 44 liters farrowed during the last half of this study. Blood oxygen values were measured directly from the piglets ear utilizing a BCI 3301 oximeter. The oximeter is a recent advancement from human biomedical technology. The oximeter allows instant measurement of the piglet's pulse rate and blood oxygen saturation level. The oximeter is based upon the differential absorption of white and near infra-red light beans passing through the tissue and blood supply of the piglet's ear.

Results and Discussion

Feeding MICRO-AID to sows in their lactation diet at the rate of 125 ppm significantly ($P<0.066$) reduced the incidence of stillbirths an average of 41% (Table 2).

Table 2. Sow Performance

	Control	MICRO-AID	%
No. of Sows	41	40	
Parity	3.61	3.23	
Feed Intake, kg	5.34	5.64	+5.6
Weight Change, kg	-3.82	-3.08	-19.4
Stillbirth/Litter	0.85[a]	0.50[b]	-41.2
Pre-Wean Mortality,%	18.09[c]	13.35[d]	-26.2

[a,b]Chi-Square = 3.48 [df]=1, P=0.066
[c,d]Chi-Square = 2.86 [df]=1, P=0.09

Pre-weaning mortality was significantly (P=0.09) lower (26.2%) in the MICRO-AID fed sows, which is consistent with the results of Jensen (1982). Sows fed MICRO-AID tended to consume slightly more lactation feed (+0.3 Kg/Day) and to lose slightly less weight (+0.74 Kg/Sow), although neither variable was statistically significant.

The greatest effects were in first litter gilts and older sows (>5 parity), where stillbirths were reduced by 85 and 54%, respectively (Table 3).

Table 3. Sow Performance by Parity

Treatment	Control			MICRO-AID		
Parity	1	2 - 4	>5	1	2 - 4	>5
No. of Sows	9	20	11	10	20	8
Feed Intake, kg	4.5	5.6	5.7	5.1	5.9	5.7
Weight Change, kg	-13.3	-2.9	3.4	-10.6	-2.3	5.8
Stillbirth/Litter	0.67[a]	0.75	1.09	0.10[b]	0.70	0.50
Piglet O2, %	68.5[c]	71.4	67.2	76.1[d]	67.2	64.8
Pre-Wean Mortality, %	19.4	16.7	19.6	11.6	11.7	20.2

[a,b] P=0.0444 [c,d] P<0.06

Blood oxygen levels of piglets at birth were significantly (P<0.06) higher for first litter gilts fed MICRO-AID compared to controls. Distribution of stillbirths by birth order was studied in the 44 litters where blood oxygen values were measured. The greatest incidence of stillbirth (62.5%) in control females occurred in the last third of the birth order. Females fed MICRO-AID exhibited a significantly different distribution of stillbirths (Table 4) due the reduction of stillbirths in the last third of the birth order. Blood oxygen values were not found to be well correlated with either birth order or birth interval.

Table 4. Distribution of Stillbirth by Birth Order

	Control	MICRO-AID
First Third	2	0
Middle Third	4	6
Last Third	10	4

Conclusions

Data from this research study supports the theory that feeding MICRO-AID to sows prior to the start of farrowing increases the blood oxygen supply to the fetus during birth thus lowering the incidence of stillbirths and reducing pre-weaning mortality.

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Amino Acid Requirements in Lactating Sows: A Review.

1. Introduction.

The metabolism of amino acids in lactating sows is not as well understood as it is in growing pigs, and the area is currently surrounded by some controversy. Historically, amino acid requirements for lactation have been derived from studies based on the empirical approach in which one or more response variables are related to different dietary inputs. The recommendations obtained by this procedure may be representative only under the experimental conditions under which they have been undertaken. *"Extrapolation to other production conditions that differ with regard to environment, management, animal factors or intensity of production is ambiguous"* (Noblet et al., 1990). Another difficulty to overcome in assessing amino acid requirements for lactating sows is the choice of response variable. In most studies, daily milk yield or litter weight gain have been the preferred response criteria. However, lactation induces a strong homeorhetic drive for directing nutrients towards milk production (Baumann and Currie, 1980), which usually results in a certain degree of mobilization of body amino acids in order to support milk production. Maximum response in terms of milk production and litter weight gain can, therefore, be achieved even in situations where the diet does not provide optimum levels of nutrients. However, the effect of body mobilization on subsequent reproductive performance has usually not been taken into account when amino acid requirements have been derived. However, recent data suggest that the amino acid requirement for optimal reproductive performance in terms of weaning to estrus interval, farrowing rate and litter size is considerably higher than the requirement for maximal milk production (Wilson et al., 1996). The importance of dietary regiments on reproductive performance may become more pronounced in the future as the industry moves toward very early weaning.

It may be possible to overcome some of the limitations of the use of empirically obtained data for assessing amino acid requirements by doing factorial calculations to describe the dietary needs for the lactating sow. By doing so, the specific needs for important body functions have to be described and quantified. It should be possible to determine estimates of nutrient requirements this way. (Noblet et al., 1990, Pettigrew et al., 1993a). In the following review, an attempt to calculate amino acid requirements during lactation using estimates for various body functions is made.

2. Assumptions for factorial calculations

In order to calculate the amino acid requirement during lactation, several assumptions have to be made. A brief discussion follows.

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2.1. Maintenance requirement

Values for amino acid requirements for maintenance in lactating sows are not easily obtained, and we are unaware of any studies where such data have been obtained using modern genotypes at high production levels. Only data from other species (Owens et al., 1985, Owens and Pettigrew, 1989) or data obtained with growing pigs (Fuller et al., 1989) or non-lactating sows (Baker et al. 1966a,b,c, Baker and Allee, 1970) are available. However, given the relatively low requirement for maintenance during lactation compared to the requirement for milk production, small mistakes in these values will not have a great impact on the overall amino acid requirement. Pettigrew (1993) summarized maintenance requirements for growing pigs, rats and humans, and suggested these could be used for lactating sows with some modifications. In the following, these values are used, and the requirement for maintenance is considered being constant throughout lactation and independent of level of milk production.

2.2. Requirement for milk production

The lysine requirement for milk production has been estimated to be 26 g of lysine per kg of daily litter weight gain. (Pettigrew, 1993, Patience, 1994). The requirements for methionine, total sulphur containing amino acids (SAA), threonine and tryptophan were estimated as 26, 54, 66, and 18 % of that for lysine, respectively, by Etienne et al. (1993). Pettigrew (1993) agreed on the estimates for methionine and tryptophan, whereas he estimated the requirements for SAA and threonine at 45 and 58 % of lysine, respectively. It should be noted that these estimates are based on the assumption that all amino acids in milk are converted from plasma amino acids to milk protein amino acids with the same efficiency. In dairy cows, it has been shown that significant differences exist in the efficiency of converting plasma amino acids into blood amino acids (Bickerstaffe et al., 1974, Spires et al., 1975). Recent data indicate that also in lactating sows, the efficiency of utilization differs between amino acids (Trottier and Easter, 1995). Possible reasons for these differences might be that components other than free amino acids in plasma, e.g. albumin, GSH or dipeptides, might contribute to the production of milk protein amino acids (Atroshi et al., 1986, Blackwell et al., 1994), or that dispensable amino acids are synthesized from indispensable amino acids (Bequette et al., 1994). Also, protein turnover within the mammary gland has been shown to be considerable. Oddy et al, (1988) estimated that milk protein output represents only 40-60 % of total protein synthesis in the lactating mammary gland of goats. Based on these reports, it could be concluded that the assumption of equal efficiency of utilization of indispensable amino acids for milk production is probably not valid, but at this point, no data on the efficiency of utilization in the lactating mammary gland of sows under various dietary conditions are available. Hence, the mean values from the above mentioned estimates will be used in the following calculations.

2.2. Feed intake during lactation.

Sows given ad libitum access to feed do not eat the same amount of feed per day throughout lactation. Recent data from the University of Illinois suggest that first parity sows eating 4.5 kg per day on average during a 21 day lactation period will eat four kg per day during the first week of lactation, 4.5 kg per day during the second week, and five kg per day during the third week (Trottier; 1995, personal communication). A similar feed intake curve will be assumed in the following calculations.

2.4. Daily milk production

Several experiments have shown that sows nursing nine to ten piglets have an average daily milk production of eight to ten kg. (Noblet et al., 1990, Stahley et al., 1990, Etienne et al., 1993). Assuming it takes approximately four kg of milk to produce one kg of litter weight gain (Patience, 1994), this level of milk production would be sufficient to support 2 to 2.5 kg of litter weight gain per day. However, pigs do not have a constant weight gain throughout the nursing period, hence, the demand for milk is not the same throughout lactation. Patience (1994) estimated the growth during a three week lactation period to occur with 25% during the first week, 33% during the second week, and 42% during the third week. A similar partitioning of milk production can be assumed, since milk production is closely related to litter growth rate (Noblet and Etienne, 1987). Under these circumstances, it can be calculated that a litter gaining 2200 g per day on average during a 21 day lactation period, will have a daily growth rate of 1650 g during the first week, 2200 g during the second week, and 2750 g during the third week. The daily milk production necessary to support such a growth rate would be 6.6 kg, 8.8 kg, and 11 kg during weeks 1, 2, and 3, respectively.

2.5. Composition of body protein

If dietary amino acids do not meet the requirements, sows can react by mobilizing body protein and(or) by decreasing milk production. The composition of body protein in sows has not been estimated, but in several studies, the composition of body protein in growing pigs has been reported.

In table 1, the average amino acid composition of body protein of growing pigs from six different studies is shown. In the following discussion, these values will be used.

Table 1 Amino acid composition of body protein. Average of six studies.[1]

Amino Acid	g/kg body Protein	Ratio
Lysine	64.5	100
Methionine	19.65	30.5
Methionine + Cystine	31.2	48.4
Threonine	37.6	58.3
Tryptophan	7.7	11.9
Valine	44	68.5

[1]Moughan and Smith, (1987), Campbell et al. (1988), Batterham et al., (1990), Kemm et al., (1990), Kyriazakis and Emmans, (1993), Bikker et al., (1994a).

[2] Tryptophan values were reported in only 3 studies.

3. Total amino acid requirements during a 21 day lactation period.

Using the above assumptions, the total amino acid requirement for a 21 day lactation period can be calculated as shown in table 2.

Table 2. Amino acid requirements (g/day) for lactating sows producing an average of 8.8 kg of milk per day during a 21 day lactating period.

		Week 1		Week 2		Week 3	
	RMa*	RMi**	RTo***	RMi**	RTo***	RMa**	RTo***
Lysine	2.09	42.9	45.0	57.2	59.3	72.0	74.1
Methionine	0.48	11.1	11.6	14.8	15.3	18.6	19.1
Met+Cys	2.63	21.0	23.6	28.0	30.6	35.3	37.9
Threonine	1.76	26.6	28.4	35.5	37.2	44.7	46.5
Tryptophan	0.59	7.7	8.3	10.3	10.8	13.0	13.6
Valine	1.07	31.5	32.6	42.0	43.1	52.8	53.9

*.R equirement for maintenance. ** Requirement for milk production. *** Total requirement.

Due to the increase in litter weight gain and subsequently in milk production, a considerable increase in the requirement for amino acids occurs with the advance of lactation. It should be noted that the amino acid requirements listed in table 2 are total amino acids. Assuming a lysine content of 7.5 % in milk protein (Pettigrew, 1993), the figures in table 3 corresponds to an overall efficiency of incorporating dietary lysine into milk lysine of 70 %. In a recent experiment, the efficiency of converting dietary lysine into body lysine in growing pigs was estimated to be 74 % (Bikker et al. 1994b).

Assuming a feed intake pattern of 4, 4.5, and 5 kg per day during the first, second and third week of lactation, as described above, the total amino acid intake during each week of lactation obtained by feeding a 0.9 % lysine diet can be calculated as shown in table 3. If that same 0.9 % lysine diet is fortified with synthetic lysine, methionine, threonine and tryptophan to yield a 1.2 % lysine diet, the total daily intake of amino acids will increase to the levels shown in table 4.

Table 3. Amino acid intake during lactation from a 0.9 % lysine diet.

	Week 1		Week 2		Week 3	
	Intake	% of Req.	Intake	% of Req.	Intake	% of Req.
Lysine	36	80	40.5	68	45	61
Methionine	11	95	12.6	83	14	73
Met.+Cys	24	102	26.6	87	29.5	78
Threonine	26	91	29.7	80	33	71
Tryptophan	8	96	9	84	9.9	73

Valine	34	104	38	88	42.4	78.6

Table 4. Amino acid intake during lactation from a 1.2 % lysine diet.

	Week 1		Week 2		Week 3	
	Intake	% of Req.	Intake	% of Req.	Intake	% of Req.
Lysine	48	107	54	91	60	81
Methionine	14.4	124	16.2	106	18	94
Met.+Cys	26.4	112	30	98	33	87
Threonine	31	110	35	94	39	84
Tryptophan	10	120	11.3	105	12.5	92
Valine	34	104	38	88	42.4	78

It appears from table 3 that a 0.9% lysine diet does not provide sufficient levels of amino acids to support milk production. Breakdown of body protein will be necessary throughout lactation in order to provide enough amino acids for milk protein synthesis. It is also apparent that this diet does not provide amino acids on an ideal basis. This can be seen from the fact that not all amino acids are present as the same percentage of the requirement. Lysine is clearly the first limiting amino acid.

From table 4, it appears that the amino acid deficiency could be partially ameliorated by feeding the 1.2% lysine diet. During the first of lactation, all amino acids are present in excess of the requirement, during the second week some of the amino acids are present above the requirement, whereas all amino acids are deficient during the third week. Breakdown of body protein will occur during the second and third week, but at a lower rate than if the 0.9% diet was fed. Lysine and valine seems to be approximately equally deficient. The extent of body protein breakdown can be calculated by comparing the values in table 2 with those in table 3 and 4, respectively. Sows fed the 0.9% lysine diet will have a need for 9 g of lysine catabolized from body stores per day during the first week of lactation, calculated as the difference between the requirement (table 2) and the actual amount provided (table 2). With 6.45 g of lysine per 100 g of body protein (table 2), a total of 140 g of body protein needs to be catabolized daily during the first week of lactation. These 140 g of body protein also provides a total of 2.7 g of methionine, 5.25 g of threonine, and 1.1 g of tryptophan, which is also available for milk production. By adding these amounts to the amounts provided from the diet (table 3), it appears that all amino acids are now present at or above the requirement. Similar calculations reveal that the need for total lysine supplied from body protein is 19 g per day and 29 g per day during the second and third week of lactation, respectively. These amounts of lysine corresponds to 295 g and 450 g of protein broken down from body stores daily during week two and three of lactation. Therefore, a total of 6.195 kg of body protein is needed for milk protein synthesis during a 21 day lactation period under these circumstances. Doing the same type of calculations for the 1.2% lysine diet shows that only two kg of body protein needs to be mobilized in sows fed this diet. It should be kept in mind that the above calculations are based on an average daily feed intake of 4.5 kg. If sows were eating 6.5 kg of feed per day and fed the 0.9%

lysine diet, they would be in a negative lysine balance only during week three, and they would be fed excess lysine on the 1.2% diet throughout lactation.

4. Conclusion

The above calculations rely on a series of untested assumptions and interpretations of data from many different experiments with different genotypes, different management conditions and different production levels. For instance, the lysine requirement of 26 g per kg of litter weight gain was calculated by Pettigrew (1993) by comparing seven different experiments conducted over 20 years in Europe and the United States. However, the data presented are probably the "best guess" that can be derived from current knowledge. Two important conclusions can be derived from these data:

- **1.** The numbers in table 2, indicate that the need for amino acids in high producing lactating sows might be considerably higher than prescribed by current recommendations (NRC, 1988), if weight loss during lactation should be avoided, but they are in good agreement with the numbers estimated recently by Aherne (1995). If a close connection between loss of body protein during lactation and subsequent reproductive performance exist, as suggested by Wilson et al. (1996), the above data seems to indicate that higher amino acid levels need to be fed during lactation in order to improve reproductive performance. If sows are only eating 4-5 kg of feed per day, a very high amino acid concentration in the diet may be required in order to obtain optimal reproductive performance.The estimated amino acid requirements also exceed what has been estimated as the amino acid requirement in most empirical studies, i.e. by Stahley et al.(1990), Johnston et al. (1991) and Etienne et al. (1993). In these studies, the optimum daily intake of lysine was estimated at 45 to 50 g. Several reasons are likely to account for the difference between these studies and the above calculations. Firstly, in the studies mentioned, no attempt was made to differentiate the requirement between the first, second and third week of lactation. Secondly, the conclusions were based only on litter weight gain and daily milk yield, whereas subsequent reproductive performance was ignored. Thirdly, no attempt was made to differentiate between dietary lysine and lysine obtained from mobilized body stores; thus, it is likely that in addition to the estimates for dietary lysine, lysine from body stores have also been utilized by these sows.

- **2.** The above calculations are based on a summary of empirically obtained conclusions rather than real factorial calculations based on rates of efficiencies during various metabolic pathways. It is apparent that at present, it is not possible to estimate amino acid requirements based only on factorial calculations, because there is a lack of data to be used in such calculations. For instance, the calculations rely on the untested assumption that no obligatory changes in amino acid content of internal organs takes place during lactation. It may well be that such changes indeed occurs - e.g. in the liver, the uterus and(or) the mammary gland. However, at this point no information on these issues exist, and more research in the area is needed in order to fully understand the amino acid metabolism in lactating sows.

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Dietary Energy Concentration Effects Carcass Leanness in Finishing Hogs.

Background.

During the finishing phase of the growing period, the pig's ability to consume feed usually exceeds its capacity for protein deposition (Whittemore, 1987). Consequently, a relatively large portion of the energy ingested during this period is deposited as carcass fat, thus lowering the protein to fat ratio in the carcass. In numerous experiments, restricting feed intake during the finishing phase has been shown to have a favorable influence on carcass leanness (Veum et al., 1970, Kanis, 1988, Williams et al.,1994). The reason for this is that a moderate decrease in daily energy intake leads to a decrease in daily fat deposition, whereas protein deposition can be maintained at the maximum level (Campbel et al. 1985). However, restricting feed intake is not possible on many commercial swine operations, because the equipment is usually designed for ad libitum feeding. Hence, it is necessary to examine other possibilities for decreasing daily energy intake under these circumstances.

The effects of dietary energy concentration on total energy intake has been examined in a few experiments. Working with growing pigs from 20 to 45 kg, Campbell and Taverner (1986) showed that voluntary food intake as measured in kg per pig per day was not influenced by the energy concentration of the diets. Hence, pigs receiving diets with a low energy concentration consumed less energy per day than did pigs fed a diet with a high energy concentration. Consequently, less fat was deposited in the carcass of pigs fed low energy diets. A similar conclusion was reached by Cook et al., (1991). Contrary to this, in experiments with finishing pigs, it has been indicated that pigs heavier than approximately 50 kg live weight compensate for being fed a low energy diet by increasing daily feed intake (Cole at al., 1967, Kennelly and Aherne, 1980). These findings have led to the conclusion that "pigs eat to meet their energy requirement". If this is true, it would seem impossible to decrease daily energy intake, and thus, decrease daily fat deposition, by feeding low energy diets to finishing pigs. However, in European experiments conducted with very lean genotypes, a constant daily feed intake in kg per day has been reported regardless of dietary energy concentration (Just, 1984, Håkonsson and Lundeheim, 1993). In these experiments, daily energy intake has been decreased by feeding diets with a low energy concentration, and the protein to fat ratio in the carcass has been enhanced.

Due to the increased importance of being able to market lean hogs, we found it of interest to investigate the effect of dietary energy concentration on carcass leanness in a modern genotype.

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Objective.
The objective of the present experiment was to examine the hypothesis that carcass leanness in ad libitum fed finishing pigs is negatively correlated with the dietary energy concentration if diets are diluted with fibers and fed to pigs during the finishing period.

Materials and methods.
One hundred and fifty barrows arising from the matings of Camborough 15 females to PIC Line 326 boars (Pig Improvement Company, Franklin, Kentucky) were allotted to one of five treatment groups at an approximately weight of 54 kg in a randomized complete block design with six replicates per treatment group. Each replicate contained 25 pigs and there were five pigs per pen. Each pen was considered an experimental unit. Five different energy levels were examined against each other in the design shown in table 1.

Table 1. *Experimental design.*

Group #	1	2	3	4	5
Kcal/kg	3,500	3,300	3,100	2,900	2,700

Pigs were housed in the finishing building at the Swine Research Center, University of Illinois. The facilities there are similar to typical commercial production units. The pens have partially slatted concrete floors and solid side walls. Feed was provided on an ad lib. basis from a two space standard feeder. Water was provided ad lib. from a biting nipple suspended on the pen sidewall. The barn is mechanically ventilated by a negative pressure ventilation system with mechanical fans. The temperature was held at approximately 20 degrees Celsius throughout the experiment. When an approximately weight of 112 kg were reached, pigs were slaughtered at the University of Illinois abattoir, and carcass measurements were obtained. Pigs were fed the same diet during the entire experimental period as shown in table 2.

Table 2. *Composition of the experimental diets.*

Diet #	1	2	3	4	5
Ingredients, %					
Corn	67.85	75.9	62.5	49.4	36.15
Soybean meal	24.4	22.0	17.5	12.9	8.4
Fat	5.5	-	-	-	-
Wheat Bran	-	-	10.0	20.0	30.0
Corn Gluten Feed	-	-	5.0	10.0	15.0
Alfalfa Meal	-	-	3.0	6.0	9.0
Vit. + Min.	2.25	2.1	2.0	1.70	1.45

Diet 2 was a traditional corn-soybean meal diet, - this diet served as the control diet. Diet 1 was a corn-soybean meal diet with added fat, consequently, this diet had a higher energy level than the control diet. In diet 3, the energy concentration was reduced to 3,100 kcal/kg by the addition of wheat bran, corn gluten feed and alfalfa meal. In diet 4 and diet 5, the energy concentration was further reduced by the addition of higher levels of wheat bran, alfalfa meal and corn gluten feed. The lysine level in diet 5 was 0.67 %, which is 10 % above the NRC requirement for finishing pigs (NRC, 1988). The level of lysine in the other diets were adjusted in accordance with the energy level, thus, the same lysine to energy ratio was maintained in all diets. All other indispensable amino acids were supplied at a level that meets or exceeds the needs calculated using "The Illinois Ideal Protein". (Baker and Chung,1992). The reason for adding lysine at a higher level than the NRC recommendation was to make sure that the pigs potential for lean growth was not restricted by the level of lysine or other amino acids. The levels of all other nutrients were provided according to NRC recommendations (NRC, 1988).

Results.
The results from the experiment are shown in table 3.

Table 3. *Results from the growth experiment.* *

Diet #	1	2	3	4	5
Initial weight, kg.	53.9	54.7	54.4	53.6	54.1
Final weight, Kg.	113.8	113.9	111.8	112.9	111.2
Average daily gain, g.	1017^{a}	1038^{a}	1006^{ab}	931^{bc}	872^{c}
Feed intake, kg/day	2.91^{a}	3.28^{b}	3.36^{b}	3.23^{b}	3.31^{b}
Feed intake, mcal/day	10.17^{ab}	10.83^{a}	10.41^{a}	9.36^{bc}	8.93^{c}
Gain:feed, kg/kg	0.35^{a}	0.32^{b}	0.30^{bc}	0.29^{c}	0.26^{d}
Gain:feed, g/Mcal	100	96	97	100	98
Dressing, %	75.97^{a}	74.9^{ab}	74.56^{bc}	73.96^{c}	73.51^{c}
10th Rib fat, inc.	0.85^{a}	0.86^{a}	0.78^{ab}	0.70^{b}	0.69^{b}
Loin Eye Area, Inc^2	5.71	5.57	5.68	5.62	5.34
Carcass lean, %	50.78^{ab}	50.42^{b}	51.72^{ab}	52.32^{a}	52.0^{ab}
Avg. daily lean gain, g.	392^{a}	382^{ab}	386^{ab}	358^{bc}	330^{c}

*Values with different superscripts are significantly different ($P< 0.05$)

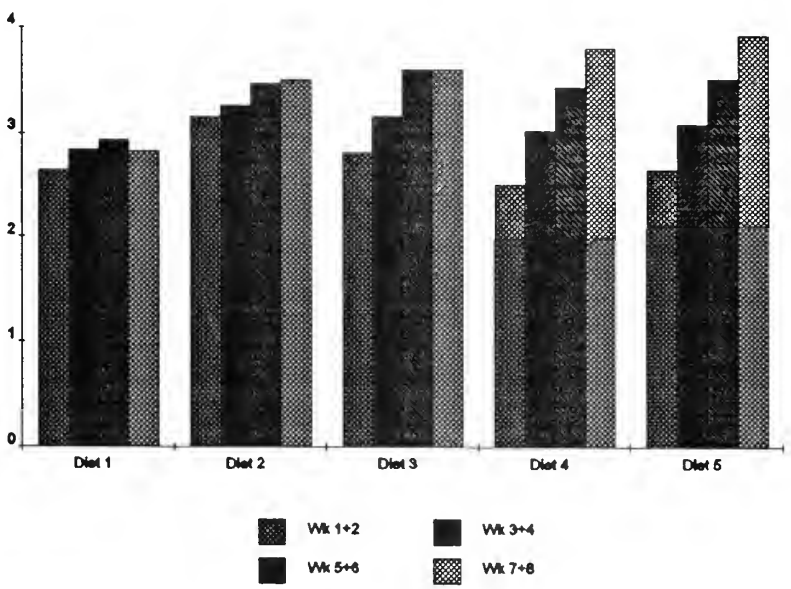
The daily weight gain of pigs on treatment diets 4 and 5 was significantly lower than that obtained

by pigs on treatment diets 1 and 2 ($P < 0.05$). In addition, pigs on treatment diet 3 also gained weight significantly faster than pigs on treatment diet 5 ($P < 0.05$). The daily feed intake in kg per pig per day was not significantly different between pigs on treatment diets 2,3, 4, and 5, but pigs on diet 1, consumed significantly less feed than did pigs on the other treatment diets ($P<0.05$). However, due to the differences in energy concentration in the diets (table 1), pigs fed diets 4 and 5 consumed significantly less calories per day than did pigs fed diets 2 and 3, and pigs on diet 5 also had a lower energy intake than had pigs on diet 1 ($P<0.05$). The gain:feed ration measured in kg decreased linearly with decreasing energy level in the diets, but if measured as gain per energy unit, no significant differences between treatment groups were observed.

Pigs on all treatment groups were killed at the same weight ($P> 0.2$), but the dressing percentage decreased significantly with decreasing energy level in the diets ($P<0.05$). Likewise, the back fat thickness tended to decrease with decreasing energy levels in the diets, and pigs on treatment diets 4 and 5 had significantly less back fat than had pigs fed treatment diets 1 and 2. The area of the loins did not differ significantly between treatment groups, although pigs fed treatment diet 5 tended to have smaller loin eye areas than pigs fed treatment diet 1 ($P = 0.099$). Pigs fed the control diet had a significantly lower lean percentage in the carcass compared to pigs fed diet 4. Pigs fed diet 1 tended to have a lower lean percentage than pigs fed diet 4 ($P = 0.074$), and pigs fed diet 5 tended to have a higher lean percentage than pigs fed diet 2 ($P= 0.075$). Pigs fed diet 1 had a significantly higher average daily lean gain than had pigs fed diets 4 ($P< 0.05$), and pigs fed diets 1, 2, and 3 had a significantly higher daily lean gain than had pigs fed diet 5 ($P<0.05$).

Since pigs were weighed biweekly, it was possible to calculate the feed intake over each two week period. This is shown in figure 1.

Figure 1. Average daily feed intake for each diet during each 2 week period.



It appears that pigs on diet 1 had a constant feed intake throughout the experiment, whereas pigs on

the high fiber diets had a lower feed intake during the initially two weeks of the experiment, and then gradually increased daily feed intake throughout the experimental period.

Discussion and conclusions.

Pigs on dietary treatments 2, 3, 4, and 5 had a similar feed intake in kg per pig per day (table 3), consequently, daily energy intake decreased with dietary energy concentration. This explains the decrease in daily growth rate observed on diets 3, 4, and 5, as compared to diet 2. S imilar observations were previously reported by Powley et al. (1981) and Chromwell et al. (1992). As expected, the decrease in daily energy intake observed in pigs fed the high fiber diets led to a decrease in daily fat deposition, and accordingly, pigs fed the low energy diets had a higher percentage of lean in the carcasses when slaughtered. Although the daily growth rate decreased with decreasing energy content in the diets, it is interesting to note that only a moderate decrease in daily lean growth rate was observed in pigs fed diets 4 and 5 as compared to pigs fed diets 1 and 2. These findings are in agreement with the reports from Just (1984) and Håkonson and Lundeheim (1993). In these two experiments, also very lean genotypes were used, thus, it may well be that modern lean genotypes are not able to compensate for a low energy concentration in the diet by increasing feed intake. However, the data in figure 1 indicate that pigs low energy and high fiber diets tends to compensate over time, and that the effect is larger during the initial weeks after the introduction of the low energy diets. This observation is in agreement with the results obtained by Kennelly and Aherne (1980), who reported, that feed intake was decreased in pigs fed low energy diets only during the growing phase, but not during the finishing phase. In our experiment, we fed pigs the low energy diets for the final 8 weeks of the finishing period, however it is possible that better results could be obtained by feeding the low energy diets for only 4 or 6 weeks. The decrease in feed intake in pigs fed diet 1 as compared to pigs fed diets 2 seems to indicate that by adding fat to a diet, a different mechanism of regulation is activated, and pigs fed the fat-containing diet did not increase their daily energy intake. This finding is in agreement with Campbell and Taverner (1986) and with Walker (1986). From these two experiments, it was also concluded that pigs do not increase daily energy intake if fat is added to the diet. The reason for this may be that passage rate of digesta is decreased when fat is added to the diet. The decrease in dressing percentage observed in pigs fed low energy diets is in agreement with Powley et al. (1981), and can be explained by an increased weight of the GI-Tract due to the higher fiber concentration in the low energy diets (Kass et al, 1980).

In conclusion, the results from this experiment indicate that it is possible to decrease daily energy intake in ad libitum fed pig. By doing so, daily fat deposition will be decreased and the lean percentage in the carcass will be increased. It should be noted that this can be achived with only a moderate decrease in daily lean gain. Hence, feeding low energy diets during the finishing period seem to be a practical way of increasing lean content in market hogs. The length of the period in which low energy diets should be fed still needs to be defined.

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A New Approach to Estimating Amino Acid Needs for Lactation

Introduction

Some would suggest that the modern era of sow nutrition research began with a 1963 paper (Clawson et al., 1963) published from the North Carolina Experiment Station. The early focus was on the effects of dietary protein level, cf., Frobish et al., 1966; Baker et al., 1970; and Hawton and Meade, 1971. There was clearly motivation to go beyond protein *per se* and develop requirement estimates for specific amino acids. The first step was the development of a purified, amino acid-based diet (Baker et al., 1966) which was employed to estimate the maintenance needs of adult females. Subsequent work at the Illinois station addressed gestation requirements using practical (Boomgaardt et al., 1972) or purified, crystalline amino acid-based diets (Rippel et al., 1965; Easter et al., 1977) Lactation requirements were examined in a decade-long series of experiments conducted in Speer's laboratory at Iowa State University, cf., Ganguli et al., 1971; Robles-Cabrera and Speer, 1983.

It is useful to understand the protocol which was used at Iowa State to determine specific amino acid requirements during lactation. The typical experiment involved 25 sows in a five-treatment experiment. The diets were based on corn, and sometimes soybean meal, with amino acid supplementation to adequacy in each case with the exception of the amino acid being investigated. The diets were fed during a 21-day lactation. The primary response criteria were: nitrogen retention, milk production, milk composition and plasma free amino acids. Litter size was typically standardized to nine pigs. With this protocol, Lewis and Speer (1973) estimated that the lactating sow requires 30 g of digestible lysine (35.3 g total) per day when producing approximately 6 kg of milk. Notable was the maternal weight loss of 10 kg during weeks two and three of the experiment. At the time a weight loss of this magnitude was considered normal.

These studies became the basis for the current estimates of amino acid requirements, cf. NRC, 1988. In the past few years a number of articles have been published in the popular press and, to a lesser extent, in peer-reviewed journals suggesting that amino acid requirements may be higher than the earlier data indicated.

Given the many factors that influence weaning weights, piglet survival and sow physiology, it is very difficult to determine amino acid requirements in large feeding studies. Thus, we decided to approach the estimation of requirements from a different perspective.

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Our approach asks the simple question, "What quantities of nutrients are removed from the blood supply by the mammary gland?" It follows that nutrient needs for milk production can be estimated from these uptake measurements. Other approaches have quantified the nutrient output in milk. However, that approach is only indicative of need because the requirements of the glands, per se, for mammary maintenance and growth are ignored.

Our approach was to examine arterial-venous differences (A-V). Figure 1 provides an illustration of how a mammary cell takes up circulating free amino acids from the arterial supply and uses these amino acids for two specific purposes:milk synthesis and mammary cell remodelling. Any amino acid not utilized should be excreted back into the venous capillary bed. The difference in A-V represents the mammary intracellular amino acid pool.

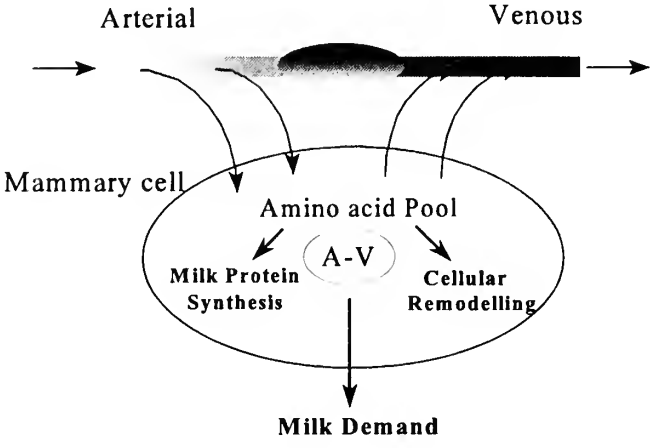

Figure 1. Uptake of Amino Acids into the Mammary Cells

Previous measurements of amino acid uptake in by the lactating porcine mammary gland can be found in two classical papers (Linzell et al., 1969 and Spincer et al., 1969). In either case the measurements were made on single samples obtained from sows. It seemed that repeated samples obtained from sows in a "normal" lactating environment would be most useful. Thus, we set out to install indwelling arterial and venous cannulas for this purpose. The arterial cannula was inserted into the carotid artery using a slight modification of the method described by (Diehl and Day, 1974). A second cannula was placed in the main anterior mammary vein using a newly developed procedure (Trottier et al., 1995). Both cannulas were passed subcutaneously to the dorsal surface of the neck where they were exteriorized and positioned for sampling.

Crossbred sows, either Camborough-15 (Pig Improvement Company, Franklin, KY) or Duroc x Yorkshire sows with an average of 2.5 parities were used in our amino acid uptake experiment. Pigs were crossfostered before day-3 of lactation to achieve a minimum litter size of 10 piglets. Dead piglets were replaced to maintain a constant milk demand. The carotid and mammary

cannulae were inserted between day-5 and day-7 of lactation and samples were obtained at intervals between day-8 and day-21 of lactation. A standard protocol was followed for each sampling. At 0800 hrs, the litter was separated from the dam and all sows were given 3.0 kg of feed. Ninety minutes later, A-V samples were drawn and the pigs were returned to the sow. Samples were drawn at 20 minute intervals for the next 100 minutes.

Table 2 illustrates arteriovenous differences for amino acids obtained in our study compared to the data reported by Linzell et al. (1969). Notice that extraction rates among amino acids vary tremendously and give an indication of the importance of a specific amino acid for mammary utilization relative to the peripheral availability of that particular amino acid.

Table 2. Mammary Extraction and A-V Difference of Essential Amino Acids

Amino acid	A-V, μmole/L		Mammary extraction, %	
	Present Experiment	Linzell et al. (1969)	Present Experiment	Linzell et al. (1969)
Arginine	42.0	47.1	34.5	26.0
Histidine	11.5	26.4	15.7	26.0
Isoleucine	32.8	43.5	39.9	30.0
Leucine	64.9	53.8	37.0	30.0
Lysine	37.3	54.0	53.0	28.0
Methionine	10.2	12.7	31.2	36.0
Phenylalanine	22.0	26.6	24.6	25.0
Threonine	31.4	31.9	20.9	22.0
Tryptophan	9.9	-	13.5	-
Valine	42.6	66.6	23.4	18.0

We were particularly interested in the relationship between lysine and valine and the changes that occurred over time. While daily average arteriovenous difference expressed as μmol/L for valine (42.6 ± 2.1) is higher than for lysine (37.3 ± 1.6), the extraction rate for lysine increased linearly ($P<.03$) with advancing lactation to reach 59% (table 3) while the extraction rate for valine remains unchanged, varying between 23 to 27 %. Among all essential amino acids, lysine is the only one being extracted at a significantly increased rate with progression of lactation, while valine has one of the lowest extraction rates. Arterial valine concentration is more than twice lysine arterial concentration and does not significantly vary during lactation while arterial lysine concentration decreases linearly with the progression of lactation. The mammary gland appears to compensate for a decreased lysine substrate availability by increasing it's extraction

rate, and consequently maintaining a constant intracellular lysine pool size. This increase in extraction rate would seem to indicate that lysine is the first limiting amino acid for mammary function.

Table 3. Extraction Rate (%) During the Course of Lactation

	Day of Lactation			
Amino Acid	11	14	17	20
Lysine	44.3	55.3	50.8	58.6
Valine	23.0	18.5	21.9	27.3

Concluding Comments

As is often the case several caveats are necessary. Extraction data reflect changes in free amino acid levels in blood during passage through the mammary system. The glands also take up amino acids in the form of peptides and intact proteins. Our data do not account for these amino acids. Although it would seem logical to use mammary uptake estimates to predict amino acid needs of the sow for milk production. That requires accurate measurement of blood flow through the mammary system. We have estimated blood flow and daily amino acid uptake using the metabolic Fick method (Linzell et al., 1974). That method assumes that a marker nutrient, i.e., lysine, is quantitatively incorporated into milk. That assumption may not be valid in early lactation since some lysine is likely being used for mammary growth.

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The Economics and Profit Potential of Hog Production

Lower market hog prices in 1994 causing lower total returns resulted in Illinois hog producer profits to decrease by $8.75 per hundredweight produced compared to 1993. Total production costs for the farrow-to-finish hog enterprises exceeded returns by $5.57 per hundredweight produced in 1994. The 1993 return was $3.18. For the five-year period, 1990 through 1994, returns exceeded production costs by $2.00 per hundredweight. All of the past five years show a positive return for farrow-to-finish enterprises except for 1994 (Table 3).

The total cost of production in 1994 averaged $41.27 per hundredweight of pork produced, compared with $41.55 in 1993 (Table 1). Feed costs made up 63 percent of total costs, or $25.93 in 1994, as compared to $25.50 in 1993. Nonfeed costs accounted for $15.34 in 1994, a decrease of 71 cents from 1993. With total returns (on an accrual basis) averaging $35.70 per 100 pounds of pork, the average producer in this group was short of covering total costs by $5.57 per 100 pounds produced. The 1993 return above all costs was $3.18.

The records for the hog enterprises reported in Table 1 were divided into groups according to the number of litters produced. The group farrowing fewer than 250 litters for the year averaged 145 litters. The group farrowing 250 or more litters averaged 551 litters.

The total cost of production per 100 pounds of pork averaged $2.07 less for the large enterprises than for the small ones. The most significant cost difference between the two groups of farms was in the feed cost per 100 pounds of pork produced. The large enterprises had a $2.90 lower feed cost than the small ones, $25.19 compared with $28.09. The $18 per ton lower price paid for commercial feeds by the larger enterprises and the 31 fewer pounds of feed that it took to produce 100 pounds of pork accounted for the lower feed cost. The number of pigs weaned per litter averaged 8.5 for the large enterprises and 8.3 for the small ones. Other production variables, such as the rate of death loss, were not significantly different.

The returns above all costs were a negative $8.12 per 100 pounds of pork produced for the small enterprises and a negative $4.69 for the large ones, a difference of $3.43. Total returns were $1.36 higher per 100 pounds of pork produced for the large enterprises as compared to the small enterprises. Management practices and production technology--such as the choice of building systems, method of transporting hogs to market, and on-farm versus off-farm systems for feed processing--may have affected the individual cost items reported in Table 1. However, the return above all costs should accurately reflect the relative profitability of the two groups of hog enterprises.

The cost data reported in Table 1 have been divided into two categories: "Cash costs" and "Other costs." This classification of production costs is important when making short-run management decisions concerning the level (volume) of production, particularly during periods of low prices.

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The average cash costs of production in 1994 ranged from about $31.32 to $33.84 per 100 pounds of pork produced (Table 1). Feed is included as a cash cost, although for most producers a major share of the grains are farm-raised The readily available alternative cash market for grain makes the farm-raised feed the same as cash.

The "Other costs" category includes depreciation, labor, and an interest charge on all capital, although on most farms part of the labor and the interest charge are cash costs. The proportion of labor that is hired largely depends on the farm's size. A one-man farm does not hire much labor, while a four-man farm may hire a major share of the labor.

The share of the interest charge that is a cash expenditure depends upon the owner's equity in the business. It could range from zero to nearly 100 percent. On most farms, some share of the interest charge will be paid in cash.

Current feed costs can be estimated by using Table 2 as a reference. For example, with the price of corn at $2.50 per bushel and the price of supplement at $16 per hundredweight, the cost of feed would be $26.10 per hundredweight of pork produced. Estimating the 1995 average annual price for corn at $2.60 per bushel and supplement at $16.00 per 100 pounds, the average feed cost in 1995 would be $26.60 per hundredweight of pork produced.

Producers should evaluate expected returns for more than one year before making new investments in hog production facilities. For 1990 to 1994, the return above all costs except management averaged $2.00 per 100 pounds of pork produced for all enterprises included in the study. The returns averaged $0.34 per 100 pounds of pork produced for the small enterprises and $2.74 for the large ones (Table 3). The difficult question confronting producers is whether or not the industry will return to the relatively favorable profit margins that existed prior to 1994. This level of profitability has resulted in expanded production, lower hog prices and reduced margins. Alternatively, will profits continue below the break-even level for an extended period of time, as in 1980-1984? The amount of continued expansion or liquidation, the strength of consumer demand for pork, and the availability of reasonably priced corn and protein supplements, will largely determine the profitability of hog production during the next five years.

Producers in the high one-third group in terms of efficiency earned an average return above all costs of $6.44 per hundredweight of pork produced for the 1990 to 1994 period (Table 3). The average for all producers during that period was $2.00 per hundredweight produced, or $4.44 less than that received by the high one-third group.

Table 4 provides an overview of the costs and returns for the farrow-to-finish hog enterprise from 1990 through 1994. It also shows the changes in three key production factors during that period--feed conversion, pigs weaned per litter and death loss. Feed conversion and pigs weaned per litter improved while death loss did not change significantly over the past five years.

The key lesson to be learned from Table 5 is that every hog producer should determine the level of production efficiency in their operation so that they can realistically evaluate the potential for profit and prospects for staying in business. It is especially important for producers who are considering expansion and for potential newcomers to the business to budget carefully by using reasonable projections of input requirements and the efficiency level that can be maintained.

Table 1. Costs and Returns for the Farrow-to-Finish Hog Enterprise in Illinois by Size of Enterprise, 1994

	Average number of litters per year		
	All	Under 250	250or more
Number of farms	125	32	93
Average per farm			
Number of litters	447	145	551
Pounds of pork per litter	1,980	1,936	1,985
Return per $100 of feed fed	$ 138	$ 124	$ 143
Returns above feed cost per litter	$ 193	$ 128	$ 216
Pigs weaned per litter	8.5	8.3	8.5
Death loss: percent of weight produced	2.0	2.1	2.0
Pounds of feed per hundredweight produced			
Farm grains	285	307	278
Commercial feeds	93	94	92
Total concentrates	378	401	370
Cost per 100 lb of commercial feeds	$ 15.82	$ 16.49	$15.59
Cost per 100 lb of concentrates	$ 7.02	$ 7.07	$ 7.00
Price received per hundredweight of pork sold	$ 39.90	(45.68)[a] $ 38.91	$40.24
	per hundredweight of pork produced		
Total returns	$ 35.70	(44.73)[a] $ 34.69	$36.05
Cash Costs			
Feed	$ 25.93	(25.50)[a] $ 28.09	$25.19
Operating expenses			
Maintenance and power[b]	3.00	2.96	3.02
Livestock expense	2.00	1.64	2.12
Insurance, taxes, and overhead	1.03	1.15	.99
Total operating expenses	$ 6.03	$ 5.75	$ 6.13
Total cash costs	$ 31.96	(31.37)[a] $33.84	$31.32
Other costs			
Depreciation[c]	$ 2.79	$ 1.88	$ 3.10
Labor	3.94	4.31	3.81
Interest charge on all capital	2.58	2.78	2.51
Total other costs	$ 9.31	(9.78)[a] $ 8.97	$ 9.42
Total nonfeed costs	$ 15.34	(16.05)[a] $ 4.72	$15.55
Total all costs	$ 41.27	(41.55)[a] $ 42.81	$40.74
Return above all costs[d]	$ -5.57	(3.18)[a] $ -8.12	$-4.69

[a] Figures in parentheses are for 1993.
[b] Includes utilities; machinery, equipment, and building repairs; machine hire; and fuel.
[c] Includes machinery, equipment and building depreciation.
[d] No charge was made for management.

Note: The average price of corn in 1994 was $2.44 per bushel.

Source: *Illinois Swine Report,* Number 115, June, 1995, Cooperative Extension Service and Illinois FBFM Association.

Table 5 shows the effect of production efficiency on net hog returns. The high-efficiency hog producer will have more money for debt servicing, improved family living, and reinvestment than the average or below-average producer.

Table 6 provides a summary of the quarterly United States crop reports for sows farrowing. The first two entries in each block are intentions, the third is the final number. The percent change from the preceding year is also shown. The farrowing figures from the December, 1995 *Hogs and Pigs Report* will be reported at the 1996 Swine Seminars.

Table 2. Feed Cost for Hogs Per Hundredweight of Gain[a]

Price of Supplement per hundredweight	Price of corn per bushel				
	$ 1.50	$ 2.00	$ 2.50	$ 3.00	$ 3.50
$ 12.00	$17.70	$20.20	$22.70	$25.20	$27.70
14.00	19.40	21.90	24.40	26.90	29.40
16.00	21.10	23.60	26.10	28.60	31.10
18.00	22.80	25.30	27.80	30.30	32.80
20.00	24.50	27.00	29.50	32.00	34.50
22.00	26.20	28.70	31.20	33.70	36.20

[a] Sow and litter, farrow-to-finish. The feed conversion is based on data from Illinois Farm Business Farm Management Association records, and was set at 5.0 bushels of corn and 85 pounds of protein supplement per hundredweight of pork produced.

Table 3. Returns Above All Costs by Size of Enterprise and Efficiency, 1990 through 1994, and Five-Year Averages, 1975-1994[4]

Year	Average number of litters per year			
	All	Under 250	250 or more	High 1/3 Efficiency
	per hundredweight of pork produced			
1990	9.74	7.37	11.00	14.28
1991	1.56	0.06	2.35	5.65
1992	1.09	-0.32	1.70	5.71
1993	3.18	2.71	3.34	7.58
1994	-5.57	-8.12	-4.69	1.01
Averages				
1975-1979	$ 3.87	$ 3.52	$ 4.57	NA
1980-1984	-2.26	-3.57	-0.79	2.46
1985-1989	3.12	1.32	4.22	7.53
1990-1994	2.00	0.34	2.74	6.44

[a] No charge was made for management.

Table 4. Costs and Returns Per Hundredweight, Illinois Farrow-to-Finish Hog Enterprises, 1990 - 1994

	1994	1993	1992	1991	1990
Total returns	$35.70	$44.73	$41.50	$43.92	$53.72
Feed costs	$25.93	$25.50	$24.86	$25.56	$26.46
Returns above feed costs	$ 9.77	$19.23	$16.64	$18.36	$27.26
Total nonfeed costs	$15.34	$16.05	$15.55	$16.80	$17.52
Total all costs	$41.27	$41.55	$40.41	$42.36	$43.98
Returns above all costs	$ -5.57	$ 3.18	$ 1.09	$ 1.56	$ 9.74
Pounds of feed per cwt. produced					
Farm grains	285	277	284	291	295
Commercial feeds	93	93	89	89	96
Total concentrates	378	370	373	380	391
Price of corn, per bushel	$ 2.44	$ 2.28	$ 2.35	$ 2.41	$ 2.44
Pigs weaned per litter	8.5	8.4	8.5	8.1	8.1
Death loss: percent of weight produced	2.0	1.9	1.9	1.9	1.7

Source: Annual Summary of Illinois Farm Business Records, 1990- 1994.

Table 5. Farrow-to-Finish Enterprise Summary by Level of Efficiency, 1994

		Level of Efficiency		
	All Farms	Lo 1/3	Hi 1/3	Hi 1/5
Number of litters farrowed	447	277	577	644
Pounds of pork per litter	1,980	1,888	2,029	2,110
Returns above feed cost per litter	$ 193	$ 82	$ 291	$ 324
Pigs weaned per litter	8.5	8.2	8.6	8.8
Death loss, percent of weight produced	2.0	2.5	1.8	1.8
Total return	$35.70	$33.49	$37.75	$38.26
Feed cost per 100 pounds produced	$25.93	$29.13	$23.42	$22.91
Returns above feed costs	$ 9..77	$ 4..36	$14.33	$15.35
Pound of feed per 100 pounds produced				
Farm grain	285	310	274	267
Commercial feeds	93	102	79	77
TOTAL	378	412	353	344
Cost per 100 lbs. commercial feeds	$15.82	$16.56	$15.25	$15.69
Cost per 100 lbs. concentrates	$ 7.02	$ 7.19	$ 6.78	$ 6.85

Table 6. Number of Sows Farrowing, United States, and Percent Change from Preceding Year

Date of Hogs and Pigs Report	March-May	June-August	September-November	December-February
			Sows to Farrow (000), % Change	
December '94	3186 -6		2995 NC	2858 -1
March '95	3212 -5	3018 -3		2886 NC
June ' 95	3260 -4	3052 -2	3029 +1	
September '95		3006 -3	2999 NC	2896 NC
December '95	_____			_____
March '96	_____			_____
June '96	_____	_____	_____	
September '96		_____	_____	_____
December '96	_____		_____	_____

Table 7. Hog Production Costs and Profits by Quarters, per 100 pounds produced[1]

	1988				1989			
PRODUCTION COSTS	1	2	3	4	1	2	3	4
Corn and grain	$10.10	$11.66	$14.54	$13.77	$14.31	$14.20	$12.96	$12.31
Protein	13.26	13.09	16.53	15.64	15.17	14.41	14.58	13.69
Non-feed items	17.20	16.80	16.50	16.30	15.90	15.90	15.90	15.90
TOTAL	$40.56	$41.55	$47.57	$45.71	$45.38	$44.51	$43.44	$41.90
7-MARKET PRICE	$44.69	$46.14	$44.58	$38.66	$40.78	$41.84	$46.07	$47.42
Profit or Loss (+or-)	$ 4.13	$ 4.59	$-2.99	$-7.05	$-4.60	$-2.67	$ 2.63	$ 5.52

	1990				1991			
PRODUCTION COSTS	1	2	3	4	1	2	3	4
Corn and grain	$12.74	$14.53	$13.72	$12.20	$12.96	$13.34	$13.07	$13.01
Protein	12.96	12.41	12.75	12.75	12.33	12.45	12.62	13.22
Non-feed items	16.75	17.50	17.75	17.75	17.25	17.25	17.00	16.75
TOTAL	$42.45	$44.44	$44.22	$42.70	$42.54	$43.04	$42.69	$42.98
6-MARKET PRICE	$49.45	$59.01	$57.67	$51.67	$51.50	$53.34	$50.85	$39.84
Profit or loss (+or-)	$ 7.00	$14.57	$13.45	$ 8.97	$ 8.96	$10.30	$ 8.16	$-3.14

	1992				1993			
PRODUCTION COSTS	1	2	3	4	1	2	3	4
Corn and grain	$13.36	$13.21	$11.65	$10.45	$10.87	$11.34	$11.65	$12.90
Protein	12.67	12.92	12.75	12.79	13.13	12.84	13.77	13.47
Non-feed items	16.50	16.25	16.00	15.75	16.00	16.00	16.00	16.25
TOTAL	$42.53	$42.38	$40.40	$38.99	$40.00	$40.18	$41.42	$42.62
6-MARKET PRICE	$38.68	$44.83	$43.86	$41.84	$43.96	$46.83	$47.49	$43.23
Profit or loss (+or-)	$-3.85	$ 2.45	$ 3.46	$ 2.85	$3.96	$6.65	$ 6.07	$ 0.61

	1994				1995			
PRODUCTION COSTS	1	2	3	4	1	2	3	4
Corn and grain	$14.00	$13.60	$11.10	$10.35	$11.30	$12.50		
Protein	13.90	13.22	13.18	12.62	12.41	12.24		
Non-feed items	15.75	15.50	15.50	15.25	15.50	15.50		
TOTAL	$43.65	$42.32	$39.78	$38.22	$39.21	$40.24		
7-MARKET PRICE	$45.19	$42.44	$40.07	$30.56	$38.19	$38.57		
Profit or loss (+or-)	$ 1.54	$ 0.12	$ 0.29	$-7.66	$-1.02	$-1.67		

[1]Estimates are made, using Illinois average farm market price of corn and the average price reported for commercial hog supplement for each quarter. The feed requirements were 5.4 bushels of corn and 85 pounds of commercial feeds for the period 1988-1991. The feed requirements were 5.2 bushels of corn and 85 pounds of commercial feeds for 1992 and 1993. Since 1994 the requirements were 5.0 bushels of corn and 85 pounds of commercial feed.

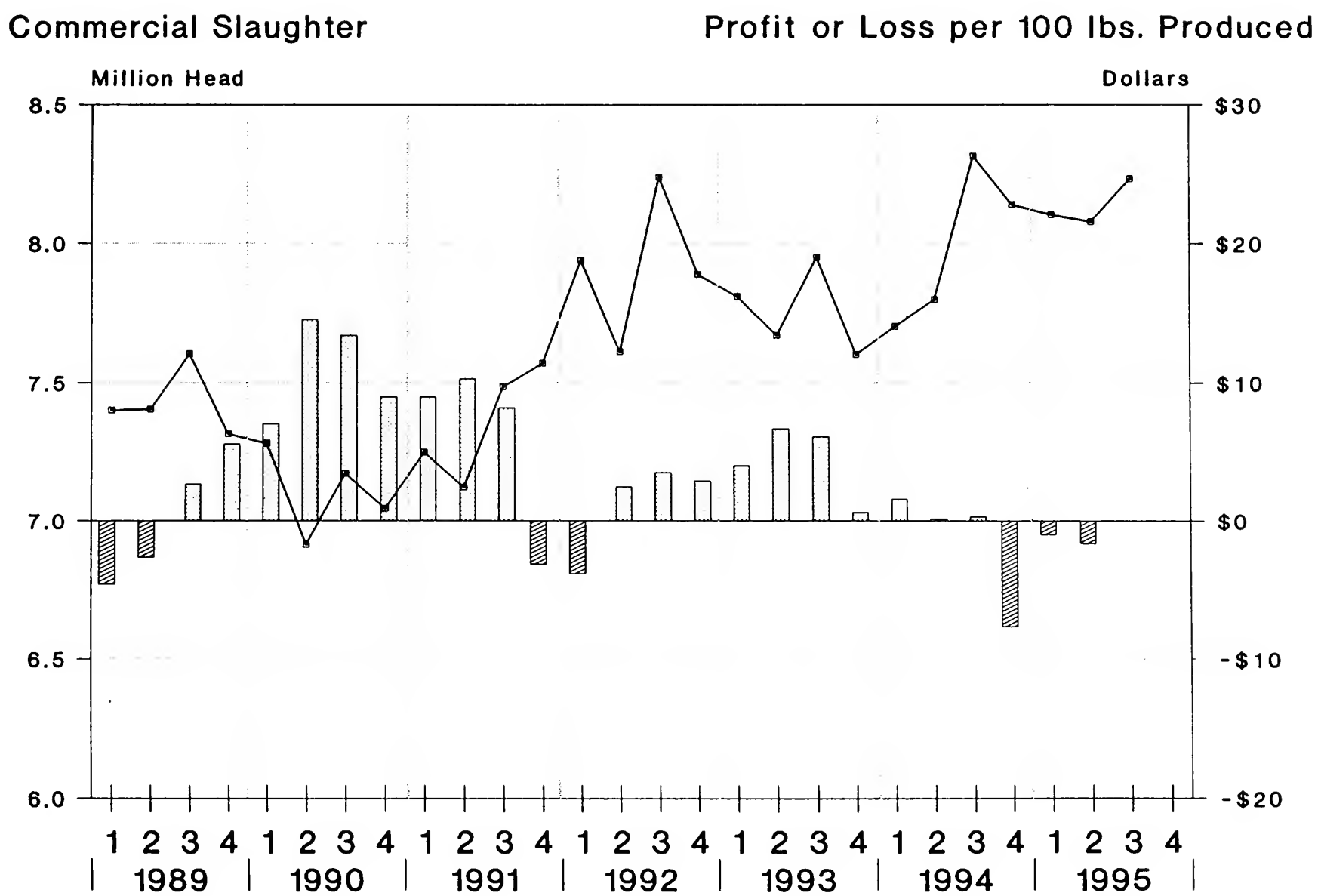

Figure 1. Relationship of Commercial Hog Slaughter and Profits Per 100 Pounds Produced.

Fumonisins Decrease Pulmonary Clearance in Swine

Introduction

Fumonisins (FB), are a group of naturally occurring mycotoxins produced by the fungus *Fusarium moniliforme*. These toxic metabolites of corn have been implicated in field cases of porcine pulmonary edema (PPE). We and others have reproduced the effects of fumonisins on swine by feeding FB-contaminated corn screenings obtained from field cases of PPE. Lethal pulmonary edema occurs at FB_1 concentrations of 100 ppm or higher. However, non-lethal hepatic and pulmonary lesions are induced at lower doses. The pulmonary effects of fumonisins include morphological changes in the pulmonary intravascular macrophages (PIMs), cells that are vital to the clearance of blood-borne pathogens and debris in pigs. Ultrastructurally, large numbers of membranous inclusions (myelin bodies of phagosomes) were found in the Kupffer cells of the liver, and the intravascular macrophages of the lung (Haschek et al., 1992).

Pulmonary intravascular macrophages are an extensive population of phagocytic cells adherent to the pulmonary capillary endothelium in select species. Their presence has been shown to be numerous in pigs, ruminants, and cats, as compared to species such as the dog, rodent, or human. While the principal site of clearance of blood-borne pathogens and debris in dogs and rodents is the liver and spleen, pigs and ruminants use the PIMs as a major component of their systemic host-defense mechanism (Crocker et al., 1981). Since PIMs are vital to the clearance of blood-borne pathogens and debris in pigs, we hypothesized that alterations in these cells could affect pulmonary clearance of blood-borne particulates and bacteria. We therefore examined the effects of short-term fumonisin exposure on the pulmonary clearance of Monastral Blue (copper phthalocyanine), which has been used extensively to study pulmonary clearance of particulates in species with active PIM populations. We also examined the effects of fumonisins on the pulmonary clearance of *Pseudomonas aeruginosa*, a gram-negative bacterium. A decrease in the pulmonary clearance of either Monastral Blue or *P. aeruginosa* would suggest that exposure of swine to fumonisins could increase susceptibility to infection. Such findings could explain the association observed between fumonisin-contaminated feed and disease in swine herds (Bane et al., 1992).

Objectives

1. To determine whether exposure to fumonisins decreased the pulmonary clearance of blood-borne particulates or bacteria,
2. To examine the potential link between fumonisin contaminated feeds and increased rates of disease in swine herds.

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Results

On necropsy following Monastral Blue infusion, the lungs were blue with control pigs having darker blue lungs than fumonisin treated pigs. Ultrastructurally, the copper appeared as dark oblong bodies primarily in the PIMs, and control pigs had a greater amount of copper evident in their PIMs than did treated pigs. Copper concentration in the lungs of fumonisin treated animals was significantly lower than in lungs from control animals.

Pigs fed fumonisin also had a significant decrease in their pulmonary clearance of *P. aeruginosa*. In addition, 3 of 6 fumonisin treated pigs died or were euthanized during the bacterial infusion, while all 6 control pigs survived the entire infusion period. Gross appearance of the lung was markedly different between the control and treated groups. Contrary to controls, in fumonisin treated pigs 60-70% of the lung appeared edematous and hemorrhagic with red to purple discoloration.

These studies clearly demonstrate that fumonisins decrease the ability of PIMs to clear infectious particulate matter and bacteria in swine, thereby potentially increasing susceptibility to disease. Our results suggest that exposure of pigs to fumonisins may increase the severity of bacterial diseases that occur on farms, thereby increasing the morbidity and mortality associated with specific diseases.

Acknowledgements

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Prevalence of Pathogenic *Yersinia enterocolitica* in Swine Herds-Preliminary Results*

Yersinia enterocolitica (Ye) is a foodborne pathogen that is estimated[1] to cause annually 3000 to 20000 cases of human disease in the United States. The most prevalent clinical signs in humans (children being the most frequently affected) are abdominal pain and fever; diarrhea, nausea and vomiting may also occur. The disease can range in severity from a self limiting gastroenteritis to potentially fatal septicemia. Pseudoappendicular syndrome has been reported,[2,3] resulting in unnecessary surgical procedures. Post-infection manifestations include reactive arthritis, erythema nodosum, and Reiter's Syndrome, auto-immune related disorders resulting from host defenses to Ye. Most recently,[4-6] it is apparent that humans can be asymptomatic and bacteremic because clinically normal blood donors supplied Ye infected blood that resulted in fatal septicemias in the transfused patients. Four of the six donors reported a diarrheal illness within 30 days of donation.[5] While the incidence of human disease attributable to *Yersinia enterocolitica* in the U.S. is less than from other major microbiological foodborne disease agents, certain biological characteristics of *Y. enterocolitica* and human population demographics and behaviors suggest *Y. enterocolitica* as an emerging microbial threat.

Ye is very tolerant to low temperatures and can continue to grow at temperatures as low as 1° C. Ye has been isolated from vacuum packaged meats[7]and can survive for extended periods in frozen food, even with repeated freezing and thawing.[8]

Of concern is the shifting of the predominant serotypes of Ye associated with human disease in the United States from serotype O:8 and O:5,27 to serotype O:3.[9,10] In Belgium, Canada, Japan, and other countries where *Yersinia enterocolitica* is a primary

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foodborne pathogen, rivaling Salmonella, Shigella, and Campylobacter, Ye serotype O:3 is the predominant serotype.[11-18] Yersiniosis caused by serotype O:3 has been identified as an emerging disease in U.S. children[10] and indigent populations.[2]

Despite the fact that *Yersinia enterocolitica* can be isolated from soil and water[19-22], flies[23] and many species of mammals and birds[20-22,24-53], these strains do not typically correlate with human clinical isolates. Swine are the only species from which Ye strains pathogenic to humans can be routinely isolated. In Belgium[54] and the United States[9,55], consumption of improperly prepared pork products has been directly related to human yersiniosis outbreaks.

Prevalence rates of swine infected with Ye are well documented in countries where Ye is a predominant foodborne disease. In Belgium,[11,12,56] Denmark,[57-59] Finland,[60] Canada[12,13,61,62] and Japan[63,64] isolation rates of Ye from swine range from approximately 35-60% of farms sampled, and 3-100% of swine within farms were infected.

In the United States, few studies of prevalence of Ye in swine have been conducted. Harmon[65] isolated Ye from 50.8% of pork tongues and 26.7% of pork carcasses. Unfortunately, none of the isolates were serotyped, but 42 isolates (of 258) showed homology with the 42 mdal plasmid associated with pathogenicity. Shayegani etal[66] reported the first isolation of serotype O:3 in the U.S., all from human sources. Isolates from pig feces (13/108) did not correspond with serotypes associated with human illness. Doyle etal[67] found 16 isolates of Ye from 31 tongues from freshly slaughtered swine. Of these, 6 were of serotype O:8 and 2 were of serotype O:3. Lee etal[9] reported more than half of chitterling containers sampled, originating from pigs slaughtered in different regions of the U.S., were positive for isolation of Ye serotype O:3.

In order to be able to address the potential emerging threat of Ye as a primary foodborne pathogen, baseline information is needed to conduct risk assessment of the U.S. swine population as a reservoir for human yersiniosis. The goal of this study is to identify the prevalence of farms whose market pig population harbors pathogenic strains of *Yersinia enterocolitica*. This data can then be applied to investigation of the epidemiology of Ye on farms and throughout the food production cycle. This may lead to the ability to identify control points that can be implemented in HAACP-based good management programs to control transmission of Ye to humans from pork products.

Materials and Methods

Ninety-six lots of market swine were randomly selected at slaughter for sampling over six approximately one month intervals. The tonsillar region of the oral cavity was

swabbed post-stunning and -exsanguination but prior to scalding at slaughter. The number of pigs per lot sampled was designated by lot size, with a target number of 45 per lot established. At collection, swabs were placed in Amies transport medium (Starswab, Starplex Scientific, Ontario, Canada) for the duration of the sampling period. Immediately at the conclusion of each sampling session, swabs were inoculated into 10 ml of Phosphate Buffered Saline (PBS) and transported on ice to the laboratory. The PBS inocula were cold enriched at 4°C for two weeks and then subcultured onto CIN (Cefsulodin-Irgasan-Novobiocin) agar (Yersinia Selective Agar, Difco, Detroit, Michigan) and incubated at 25°C for 48 hours. Any colonies exhibiting the characteristic colony morphology of Yersinia species (pink centers, clear borders) were selected for identification as *Yersinia enterocolitica* by an abbreviated scheme described by Devenish[68] using Kligler's Iron Agar and Christensen's Urea Agar slants(Remel, Lenexa, Kansas). All isolates identified as presumptive Ye were evaluated for presence of the *ail* gene using a Polymerase Chain Reaction (PCR) technique.[69] The presence of the *ail* gene has been associated[70] with virulence. Serotyping of strains will be carried out using anti-sera against Ye antigens O:1,2, O:3, O:5, O:8, and O:9 (Yersinia enterocolitica O-Grouping Antisera "Seiken", Denka Seiken Co., Ltd.Tokyo, Japan).

Information recorded for the lots of swine at slaughter were farm name, number of pigs per lot, average weight of the pigs, time of delivery and time of slaughter.

Results

Sampling has been concluded and the final groups of lots are being examined microbiologically as indicated. Thus far, 16 of 28 herds (approximately 57%) have been identified as containing pigs infected with pathogenic *Yersinia enterocolitica*. Twelve herds (approximately 43%) were negative for pathogenic strains of Ye. All twenty-eight herds sampled have had at least one isolate identified as Ye by the abbreviated scheme described previously. The percentages of market swine per lot sampled infected with pathogenic Ye at slaughter range from 2-31%.

Discussion

Preliminary findings have identified both herds that have market swine infected with pathogenic strains of Ye at slaughter and those that do not. Completion of this project will provide an estimate of the prevalence of swine farms infected with pathogenic strains of *Yersinia enterocolitica*. These data will also provide the framework for future epidemiologic investigations of potential risk factors that may be associated with infection of swine with pathogenic Ye at slaughter.

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PCR Detection of Toxigenic *Pasteurella multocida* Infections

Introduction

All too often infectious disease agents are unknowingly introduced into swine herds though movement of asymptomatic, inapparent carrier animals. To prevent this, rapid accurate tests for the infectious disease agents are needed. Rapid, accurate detection of infected animals is also critical for monitoring herd health on farms with eradication programs, making informed decisions when matching herd health for replacement seedstock (for example in the CleanStart[R] program), and performing vaccine and epidemiology studies. Progressive atrophic rhinitis is a disease with inapparent carrier animals and less than optimal tests for infection. Atrophic rhinitis is a continuing problem in swine production, causing both atrophy of nasal turbinates and reduced rate of gain (up to 20% reduction in growth rate).[2-5] Among swine producers with 200-plus sow herds, almost half report problems with atrophic rhinitis and about 60% vaccinate against atrophic rhinitis.[7] The proximate cause of the atrophic rhinitis is toxigenic *Pasteurella multocida*.[5]

Experimental Objectives

Our objective is the development of a rapid, sensitive, and specific assay to detect toxigenic *Pasteurella multocida* in pigs. Our hypothesis is that both clinical and subclinical (inapparent) infections by toxigenic *P. multocida* can be accurately detected using PCR (polymerase chain reaction) amplification of the toxin gene in nasal or tonsilar samples. PCR is a rapid, sensitive (positive result even if test quantity is minimal), and specific (no false positive results) procedure to amplify (make multiple copies of) a specific segment of DNA to easily detectable amounts.[1,6,8] Our assay will target the toxin gene of *P. multocida*; the toxin is an essential virulence factor in atrophic rhinitis.

We have designed primers and reaction conditions needed to amplify a 1000 base segment of the toxin gene in toxigenic *P. multocida*. Figure 1 shows an example of the results from sixty swine isolates that we have tested. In the nine isolates in Figure 1, our PCR assay detected the toxin gene (indicated by the 1000 base DNA band) in isolates resolved in the third, sixth, and ninth lanes. These isolates were confirmed toxigenic by direct genetic probing in colony hybridization and by testing their toxicity to mice. The PCR negative isolates were negative for toxin in these other two assays indicating the specificity of the PCR assay.

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Based on our preliminary PCR results, we have initiated a project to develop PCR detection of toxigenic *P. multocida* in pigs. The project, funded by the Illinois Department of Agriculture, is designed with three specific aims or steps. The first step is to optimize our PCR protocol for samples collected from pigs. In reconstruction experiments, we will simulate field conditions in the laboratory to optimize the assay before using research animals. For this optimization, nasal and tonsilar swabs will be collected from pigs in a *P. multocida*-free herd, inoculated experimentally with *P. multocida*, and assayed with PCR for the toxin gene. The negative control will be swabs inoculated with a non-toxigenic isolate of *P. multocida*. We will add other respiratory bacteria to the swabs to confirm specificity (no false positive tests due to other nasal bacteria being present). The second major step is to confirm the PCR protocol in experimentally infected pigs. We will induce and test clinically infected pigs and subclinically infected pigs (asymptomatic carriers). The third and last major step is to use our PCR protocol in naturally infected pigs. To do this, we will follow a group of pigs on two local farms with endemic atrophic rhinitis (constant low level disease in herd) from birth to slaughter. PCR results will be correlated with clinical signs, bacterial isolation, and lesions at slaughter (turbinate atrophy).

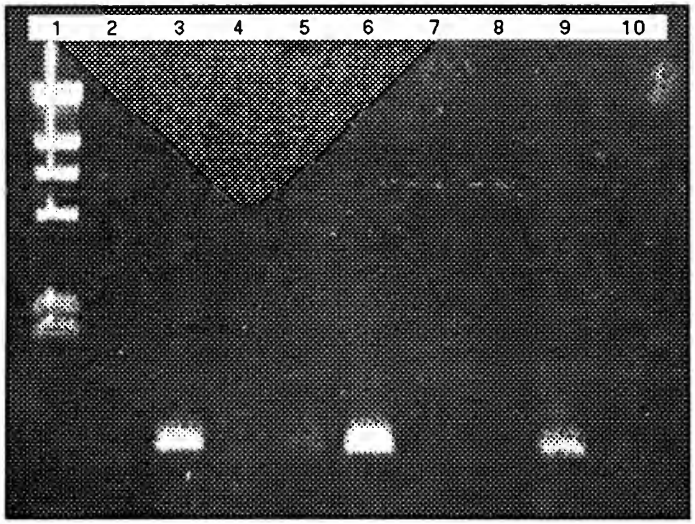

Figure 1 *Scanned photograph of agarose gel with resolved, stained DNA following PCR amplification. The bands in the first lane are size standards: 23100 to 2000 bases, top to bottom bands).*

Applications

A rapid, sensitive, specific assay to detect toxigenic *P. multocida* in swine will help diagnose and control the transmission of progressive atrophic rhinitis. The assay will allow testing of seedstock to prevent adding infected animals to a clean herd and will aid eradication programs on farms (early weaning with all-in, all-out procedures). The project will facilitate epidemiology and vaccine studies of atrophic rhinitis that have been hindered by inadequate testing procedures.

The *P. multocida* PCR assay is being designed with the intention, in future projects, to develop a multiplex assay that will simultaneous screen for several pathogens in the tonsils and nasal cavity of pigs. *Bordetella bronchiseptica*, the bacteria that often serves as the cofactor that allows colonization by *P. multocida* in atrophic rhinitis, will be the first pathogen added to the test. Then pseudorabies and porcine respiratory and reproductive viruses and *Actinobacillus pleuropneumoniae* will be added. Multiplexing the PCR should lead to economical, rapid, sensitive, and specific detection methods for many serious infectious diseases of swine.

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A Field Trial Evaluating the Immunogencity of Pseudorabies Virus Vaccines With Deletions for Glycoproteins X and I[1]

Introduction

There is considerable research indicating that modified live pseudorabies virus (PRV) vaccines with deletions for glycoprotein I (gI-) are efficacious in reducing clinical signs and viral shedding upon challenge with virulent PRV (van Oirschot et al, 1990). However, gI- vaccinated pigs with maternally derived PRV antibodies are inhibited in mounting an immune response following vaccination (Weigel et al., 1995) and are more likely to excrete virus upon challenge with a virulent strain (van Oirschot et al, 1991). Repeated vaccination of pigs is needed to provide some protective immunity against challenge with virulent virus (van Oirschot & Gielkens, 1987).

PRV vaccines with a deletion for glycoprotein X (gX) have been studied less frequently. Nevertheless, the efficacy of gX- vaccines has been demonstrated. Wardley et al. (1991), comparing gX-, gI-, and gX-gI- vaccines given to pigs from non-vaccinated sows, found that pigs receiving gX- vaccine had higher average daily gain and less virus shedding following challenge than pigs receiving gI- or gX-gI- vaccine. Comparative immunogenicity of gX- and gX-gI- vaccines under conditions of potential maternal antibody interference has not reported previously.

The study reported below compares two gX- PRV vaccines with respect to their immunogenicity under conditions of potential maternal antibody interference. One vaccine also has a gI deletion.

Methods

A commercial swine farm in Illinois was selected for this field trial. This farm was negative for PRV infection. Sows were vaccinated with a gX-gI- PRV vaccine[1] at approximately 35 days of gestation. All pigs in the study were farrowed within a 2 week period, and were 8 weeks old (± 1 week) at the time of selection.

There were 7 treatment groups. A control group consisted of pigs that were not vaccinated for PRV. Three treatment groups received a modified live gX- PRV vaccine[2], and 3 treatment groups

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1- Supported by grants from the Illinois Pork Producers Association and the Agricultural Experiment Station, University of Illinois.

[1] : PRV/Marker® Gold; Syntrovet, Inc.; Lexena, KS.
[2] : PRV/Marker® Blue; Syntrovet, Inc.; Lexena, KS.

received the same modified live gX-gI- PRV vaccine given to sows. For each type of vaccine, there were 3 vaccination schedules (representing different treatment groups): 8 weeks of age, 12 weeks of age, and 8 and 12 weeks of age. There were 15 pigs in each treatment group. Pigs were distributed among pens to equalize the ages in each pen. All of the pigs receiving one type of vaccine (including none) were housed together in the same pen. Selection of pigs within a pen for the study was determined at random.

Each pig was identified with a color-coded numbered ear tag, with the color designating the treatment group. Blood samples were drawn from each pig at 8, 10, 12, 14, and 16 weeks of age. Blood samples were sent to the Illinois Animal Disease Laboratory in Galesburg, where a screening ELISA[3] was performed to detect serum antibodies to PRV.

The outcome analyzed was the ELISA score at 16 weeks of age, with higher values associated with higher levels of PRV serum antibodies. For statistical analysis, the following (orthogonal) contrasts between treatments were examined: (1) Vaccination versus no vaccination, (2) gX- vaccine versus gX-gI- vaccine, (3) double versus single vaccination with gX- vaccine, (4) double versus single vaccination with gX-gI- vaccine, (5) single vaccination at 12 versus 8 weeks for gX- vaccine, (6) single vaccination at 12 versus 8 weeks for gX-gI- vaccine. The influence of baseline maternal antibodies (week 8 ELISA test results) was also considered. The modification of treatment effects according to baseline maternal antibody levels was also examined (Weigel & Narvaez, 1991).

Results

The results of the serological testing for PRV antibodies by age of the pigs for each treatment group are shown in Table 1.

Table 1. Percentage of pigs seropositive for PRV antibodies by screening ELISA by treatment group and age

Vaccine: Schedule: Age (weeks)	None NA	gX-gI- 12 wk	gX-gI- 8 wk	gX-gI- 8, 12 wk	gX- 12 wk	gX- 8 wk	gX- 8, 12 wk
8	33.3%	53.3%	66.7%	66.7%	66.7%	26.7%	26.7%
10	6.7%	26.7%	86.7%	100.0%	33.3%	100.0%	93.3%
12	6.7%	0.0%	66.7%	60.0%	6.7%	80.0%	86.7%
14	6.7%	100.0%	100.0%	100.0%	93.3%	100.0%	100.0%
16	0.0%	93.3%	93.3%	100.0%	100.0%	100.0%	100.0%

[3] : HerdChek®: Anti-PRV(S); IDEXX Corp; Portland, ME.

Despite efforts at equalizing treatment groups for baseline conditions, the percentage of pigs with maternally-derived PRV serum antibodies at 8 weeks of age was higher for pigs receiving gX-gI- (28/45= 62%) than for those receiving gX- vaccine (18/45= 40%). It is likely that the lower levels of maternal antibodies in the groups of pigs receiving the gX- vaccine was due to the higher proportion of offspring of gilts in these pens, as a result of the assortment of pigs after weaning by the owner.

For the treatment groups where vaccination did not occur at 8 weeks of age, the percentage of pigs with PRV serum antibodies decreased to lower levels by 10 weeks, and even lower by 12 weeks of age. In treatment groups where vaccination occurred at 8 weeks, the percentage of pigs with PRV serum antibodies increased to higher levels by 10 weeks; however, all these treatment groups had a lower percentage of pigs with PRV serum antibodies at 12 weeks than at 10 weeks. Regardless of vaccination schedule, all treatment groups except the control group had an increase in PRV serum antibody levels from 12 to 14 weeks. By 16 weeks of age, 98% (88/90) of vaccinated pigs had detectable PRV serum antibodies.

The regression analysis examined the effect of vaccine and vaccination schedule on PRV serum antibody levels at 16 weeks of age (as indicated by the quantitative value of the s-ELISA test) and the role of maternally-derived antibodies in inhibiting an immune response to vaccination. When only treatment main effects were considered, there were 3 significant differences observed. Double vaccination produced higher antibody levels than did single vaccination (gX-gI- vaccine: $p < 0.0001$; gX- vaccine: $p < 0.001$). Higher PRV serum antibody levels were achieved for pigs vaccinated at 12 weeks only compared to those vaccinated at 8 weeks only, an effect that was significant for both the gX-gI- vaccine ($p < 0.0001$) and the gX- vaccine ($p < 0.001$). The PRV serum antibody levels were also higher for the gX- vaccine than for the gX-gI- vaccine ($p = 0.022$). There were also several treatment effects that were dependent upon baseline maternal antibody levels. In general, pigs with higher maternal antibody levels showed less of an immune response to vaccination ($p = 0.001$). Vaccination of pigs at both 8 and 12 weeks was more effective than single vaccination at either 8 or 12 weeks in overcoming maternal antibody interference; this effect was observed for both vaccines (gX-gI- : $p = 0.035$; gX- : $p = 0.043$).

Discussion

As indicated by the percentage of vaccinated pigs seropositive for PRV antibodies at 16 weeks of age, both vaccines were effective in inducing a detectable immune response, regardless of the vaccination schedule. These results are different from the previous study of a gI- vaccine (Weigel et al., 1995), where fewer than half of the pigs vaccinated at 8 and 12 weeks of age had PRV antibodies detectable by a screening ELISA. One major difference from the current study is that in the previous study, sows were vaccinated 4 times per year. Other herd health factors may also have had an impact on these results.

Although all vaccine treatments were effective in eliciting detectable levels of PRV antibodies, there were several differences apparent among the treatments. The clearest treatment differences were that higher PRV antibody levels were produced by double versus single vaccination, and for single vaccination at 12 weeks versus 8 weeks. Overall, higher maternal

antibody levels at 8 weeks were associated with lower PRV antibody levels at 16 weeks, indicating maternal antibody interference with the immune response to vaccination. Baseline maternal antibody levels also moderated the effects of vaccination; in particular, double vaccination (at 8 and 12 weeks of age) was important in overcoming maternal antibody interference.

Although the antibody levels produced by the gX- vaccine were higher than those produced by the gX-gI- vaccine, the differences between these vaccines were not as apparent as the other results obtained. Thus, there was evidence supporting the argument that deletion of glycoprotein I weakens the immunogenicity of a vaccine already having a deletion for glycoprotein X; however, this evidence was not strong. Therefore, additional research is needed to determine more definitively the effects of different gene deletions on PRV vaccines.

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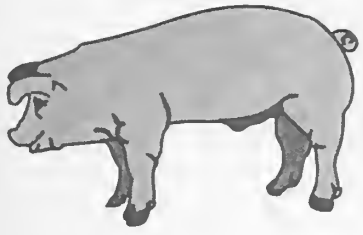

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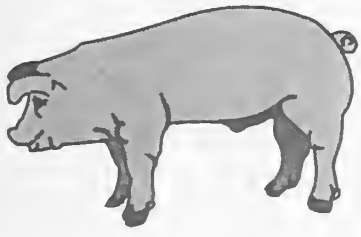

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The University of Illinois Swine Group Directory provides advice to Illinois pork producers. Fields of expertise have been included to help you select the best individual to answer your specific question. Please be advised that the individual may not be available to take your call at all times. If you leave a message that includes a brief summary of your problem(s), he or she will return your call, or will refer your message on to a more appropriate individual. 10/24/96

The University of Illinois
Swine Seminar Series
Swine Research Report

For more than 30 years, the University of Illinois Swine Extension Team has been presenting state-of-the-art research results to Illinois Pork Producers through the Illinois Area Swine Seminar Series. The Swine Extension Team is comprised of State Extension Specialists from the Department of Animal Sciences, Department of Agricultural Consumer Economics, Department of Agricultural Engineering in the College of Agricultural, Consumer and Environmental Sciences and the College of Veterinary Medicine. Also serving on the Team, and the individuals who are responsible for organizing and planning the swine seminars are Extension Educators-Animal Systems and Extension Educators/Farm Systems.

The science and technology represented in the proceedings of the swine seminars and the swine research report is a testimonial to the commitment and dedication of the current faculty and staff in the College of ACES and the Cooperative Extension Service to the improvement in the competitiveness of Illinois' pork producers. We trust that many of the studies reported herein will be of direct benefit to you.

A new endeavor that the swine faculty in the Department of Animal Sciences has undertaken is the development of a Home Page on the World Wide Web. It is referred to as **PorkNet**.

PorkNet is an integrated, information access, technology transfer system for the purpose of addressing the needs of the swine sector within Illinois. The program is led by the University of Illinois Department of Animal Sciences in collaboration withe the Departments of Agricultural and Consumer Economics (ACE) and Agricultural Engineering from within the College of Agricultural, Consumer and Environmental Sciences (ACES) and the College of Veterinary Medicine.

The goal of **PorkNet** is to provide the swine industry of Illinois with information in a rapid and timely manner to facilitate decision making. There will be two principle elements, focusing on information collection and dissemination, and the development of novel approaches to information delivery.

This page is also designed to showcase the Department of Animal Sciences at the University of Illinois along with faculty/staff from other departments within the College or ACES. The Department of Animal Sciences desires to tie the Illinois Pork Industry to the University of Illinois.

As an electronic communications and information system on the Internet, **PorkNet** takes advantage of the newest technologies to integrate up-to-date research information with data collected on individual operations to provide decision making tools for use by producers. **PorkNet** will also link other educational, association and industry related organizations to each other and to resources around the world. **PorkNet** will allow viewers to connect via electronic mail (e-mail), and provide an instantaneous method for asking questions and receiving answers from a panel of swine experts from a wide range of disciplines.

Each week, the **PorkNet** Web site will provide a "**Topic of the Week**", i.e., the latest information or research findings from various discipline areas.

An **"Ask an Expert"** section allows producers to send a question to experts in such areas as nutrition, genetics, reproductive physiology, buildings, ventilation, waste management, economics, veterinary medicine (swine health), business management, immunology, swine behavior and lactation biology. The question and answer exchange is shared on **PorkNet** for the benefit of all users.

The **PorkNet** design team is led by Dr. Mike Ellis, with assistance from Gilbert Hollis, Leif Thompson, Matthew Wheeler and Walt Hurley with the Department of Animal Sciences at the University of Illinois. Collaborating with them is Floyd Davenport, Illinois Cooperative Extension Service Office of Computer Coordination.

The URL for PorkNet will be: www.aces.uiuc.edu/~PorkNet

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COLLEGE OF AGRICULTURAL, CONSUMER AND ENVIRONMENTAL SCIENCES

Department of Animal Sciences

COLLEGE OF VETERINARY MEDICINE

Departments of Veterinary Pathobiology and Clinical Medicine

Using High-Oil Corn in Swine Diets

Gilbert R. Hollis and Robert A. Easter
Department of Animal Sciences
University of Illinois

Corn is the primary energy source in swine diets. Therefore, finding ways to enhance the amount of digestible energy available in corn is a logical approach to increasing energy levels in rations while avoiding the handling problems commonly associated with supplemental fat. Through genetic selection, plant breeders have developed corn varieties with significantly higher oil content. This type of genetic engineering is nothing new. High-lysine and high-oil varieties have been available for years. What is exciting is that high-oil varieties are now available that experience little reduction in yield when planted at about an 8% higher population. These high-oil corns differ from regular corn because a greater portion of the kernel is made-up of the germ, resulting in not only higher oil levels but higher lysine levels than regular corn. Corn oil contain over twice as much energy (calories) as does an equal weight of cornstarch. Thus, high-oil corn provides the pig with more available energy per bushel than does regular corn.

To get maximum benefit from high-oil corn, a nutrient analysis is imperative. There are major differences among varieties, plus considerable variation due to growing conditions and location. High-oil corn should be treated as an entirely different feed ingredient. Mixing high-oil corn with regular corn dilutes the potential benefit.

Crude protein levels are usually greater in high-oil corn than conventional corn. However, crude protein levels of high-oil corn can be misleading. As with conventional yellow corn, lysine levels are not always proportional with crude protein. Therefore, formulating rations based on crude protein is not an acceptable parameter if nutritional accuracy is the goal. Lysine and tryptophan levels are also in higher concentration in high-oil corn. Since lysine is the first limiting amino acid for swine, matching the amount of lysine in the diet with the pigs' needs for lean growth is critical.

The hybrid corns commonly used in swine diets contain, on the average, about 3.5% crude fat (oil). Most high-oil corn varieties in production today have a crude fat content between 6% and 8%. This compares to about 3.6% in conventional corn. The lysine level for most high-oil corn comes in between .28% and .30%, compared to the NRC rating of .25% for dented yellow corn.

Armed with a nutrient analysis of the corn supply, expected feed intake and an estimation of the hogs' genetic potential for lean growth, rations can be formulated for maximum performance. If high-oil corn contains 6% to 7% fat, the fat content of most nutritionally-accurate diets will be increased 40 to 50 lbs. per ton. This level of fat is similar to rations that use supplemental fat to control dust. The additional energy should enhance feed conversion, but is unlikely to have much impact on growth rate.

The energy content of a feed is measured in kilocalories (kcals). Normal corn has 1554 kcals of net energy per pound while high-oil corn has been shown to have about 1624 kcals (Adams and Jensen,

1987). It is useful to examine a similar energy difference that exists between sorghum grain (milo) and normal corn. Sorghum grain has only 95-96% of the energy content of normal corn. Pigs fed a sorghum grain-based diet require more feed to gain the same amount of weight than similar pigs fed a regular corn-based diet. For this reason, producers are usually advised to pay no more than 95% of the price of normal corn for sorghum grain. Because high-oil corn has more energy per pound it could be valued at a higher price than regular corn.

As early as 1972, Nordstrom, et al. demonstrated that feed efficiency could be improved by substituting a high-oil (6.7% to 8.5% oil) corn for a normal (3.5% oil) corn. In the years that followed, research by corn breeders was directed at incorporating the genetic basis for the high-oil content in commercially viable lines of corn. Sufficient progress was made by the mid-1980's to justify an in-depth evaluation of the feeding value of high-oil corns for pigs. The work was conducted in the Department of Animal Sciences at the University of Illinois by Dr. A. H. Jensen and his graduate students.

Two experiments involving 186 pigs were conducted to determine the utilization of high-oil corn (HOC) by young pigs. The first experiment involved nursery-age pigs weaned at 28 days of age, with an average weight of 23.1 lbs and were on test for 28 days. The diets used are shown in table 1. The basic diet was quiet simple, employing only corn, soybean meal, sources of vitamins and

Table 1. Composition of diets for nursery pigs[1]

	Diet Number			
Ingredient	1	2	3	4
Ground regular corn	72.50	------	70.47	70.50
Ground high-oil corn	------	72.77	------	------
Soybean meal (48%)	24.00	23.60	24.64	26.00
Corn oil	------	------	1.39	------
Dicalcium phosphate	1.50	1.50	1.50	1.50
Limestone	1.25	1.25	1.25	1.25
Trace-mineralized salt[2]	.35	.35	.35	.35
Vitamin mixture[3]	.20	.20	.20	.20
Antibiotic[4]	.20	.20	.20	.20
L-lysine-HCl (78% lysine)	-------	.13	-------	-------
TOTAL	100.00	100.00	100.00	100.00
Calculated Analysis:				
Protein, %	18.02	18.10	18.10	18.80
Lysine, %	.89	.94	.91	.94
Gross energy, kcal/lb.	1731	1822	1759	1731

[1]Adams and Jensen, 1987

[2]Provided the following per lb. of diet: NaCl, 1.32 grams (maximum), 1.24 (minimum); Zinc, 45.4 mg; Iron, 41 mg; Manganese, 9.1 mg; Copper, 3.62 mg; Cobalt, 0.34 mg; Iodine, 0.16 mg; Selenium, 0.04 mg.

[3]Provided the following per lb. of diet: vitamin A, 3,000 IU; vitamin D_3, 300 IU; vitamin E, 20 mg; choline chloride, 150 mg; nician, 15 mg; d-pantothenic acid, 5.5 mg; riboflavin, 1.0 mg; vitamin B_{12} activity, 16 mcg.

[4]Provided 44 ppm chlortetracycline.

minerals and an antibiotic. Diet 1 was a practical formulation that used normal corn and soybean meal. In the second diet, high-oil corn was used in lieu of normal corn and the formulation was equal to diet 1 on the basis of lysine to energy ratio. The energy content of diet 2 was raised over diet 1 by the addition of the high-oil corn. In order to maximally utilize the additional energy, extra lysine was added in the form of synthetic L-lysine HCl. Diet 3 was prepared using normal corn and corn oil was added to a level equal to that found in diet 2. The purpose of diet 3 was to determine if the oil in the ground whole corn was as well utilized as oil that had been removed from corn by milling. Diet 4 was formulated to be equal to diet 2 in lysine content to determine if the response to high-oil corn was, in fact, a response to the additional lysine it contains. In this instance, the additional lysine was obtained by increasing the amount of soybean meal in the normal-corn diet.

The results of the experiment are shown in table 2.

Table 2. Results of feeding young pigs high-oil corn[1]

	Diet Number			
Corn	Normal	Hi-oil	Normal	Normal
Energy/Lysine Response	4.28	4.27	4.25	4.06
Initial weight, lbs	21.40	21.49	21.40	21.38
Daily gain, lbs	.83	.85	.81	.84
Daily feed, lbs	1.66	1.54	1.55	1.61
Feed/gain	1.99	1.83	1.91	1.92

[1]Adams and Jensen (1987)

Pigs responded to the high-corn diet (diets 2 and 4) by maintaining the same rate of gain with less feed. In the comparison of diet 2 to diet 1, there was an eight percent improvement in feed efficiency. The comparison of diet 4 to diet 1 is of interest and may suggest that a part of the improvement in feed efficiency by pigs fed high-oil corn is due to the additional lysine in that product.

Adams and Jensen (1987) conducted several additional growing/finishing pig experiments to determine the precise lysine to energy ratio that would give the best growth response in diets formulated with high oil corn. In addition, they conducted an experiment to determine if any changes in carcass merit resulted from the higher level of oil in the diet. Loin-eye area, backfat thickness and carcass length were, in each comparison, unaffected by replacement of normal corn with high-oil corn. Because corn oil is rich in unsaturated fatty acids, Adams and Jensen (1987) analyzed samples of backfat and found that fat from pigs fed the high-oil corn had higher levels of unsaturated fatty acids. There was no evidence that this contributed to "soft pork" and a loss in carcass value.

The final experiment conducted in this series involved feeding high-oil corn to sows in late gestation and throughout a 28-day lactation. The results are presented in table 3.

Table 3. Effect of feeding high-oil corn on swine reproduction[1]

	Corn type		
	Normal	High-oil	High-oil
Protein, %	12.1	13.9	13.3
Lysine, %	.48	.52	.48
Mcal/% lysine	7.88	7.64	8.28
No sows	13	13	13
Daily gross energy intake, Mcal	7.76	8.15	8.15
Avg. Wt. gain in late gestation, lbs	22.88	39.38	39.16
Pigs/litter, born alive	10.1	9.4	10.4
Avg. piglet weight, lbs			
birth	3.36	3.47	3.58
weaning	16.06	16.5	15.62

[1]Adams and Jensen (1987)

Although a limited number of sows were involved in the experiment, feeding high-oil corn increased average energy intake and improved maternal weight gain in late pregnancy. There were tendencies for an improvement in birth weight and weaning weight but the results were not consistent. Other data provided evidence of an eight percent increase in fat content of the sow's milk.

Table 4. Nutrient composition of regular and high-oil corn

Nutrient	Regular corn	High-oil corn
Protein, &	8.0-8.8	9.2-10.8
Lysine, %	.24	.28
Tryptophan, %	.06	.066
Threonine, %	.29	.32
Meth. + Cystine, %	.35	.38
Oil, %	3.5	6.0-7.5
Net energy, kcal/lb	1554	1624

Summary

Research conducted to date provides good evidence that feed efficiency in swine can be improved by substitution of high-oil corn for normal corn. As in all formulations, care must be taken to insure that a proper lysine to energy ratio is maintained. The carcasses from pigs fed high-oil corn diets are virtually identical to those of pigs fed normal corn. Use of high-oil corn diets increases the fat content of sow's milk and probably the weaning weight of piglets although the experiment described

in this report did not demonstrate that.

There may be other, more subtile benefits from using high-oil corn diets for swine. These could include reduction of the dust in the hog-house environment and reduced wear on feed-handling equipment.

Recommended Dietary Formulations Using High-Oil Corn

On the following pages can be found examples of dietary formulations using High-Oil corn for various classes of swine. There are recommended dietary formulations for:

1. Gestation
2. Lactation
3. Starter 1 (9-15 pound pigs)
4. Starter 2 (15-25 pound pigs)
5. Starter 3 (25-50 pound pigs)
6. Growing Pigs (50% Lean Yield)- with 44% or 47% SBM
7. Growing Pigs (52% Lean Yield)- with 44% or 47% SBM
8. Growing Pigs (54% Lean Yield)- with 44% or 47% SBM
9. Finishing Pigs (50% Lean Yield)- with 44% or 47% SBM
10. Finishing Pigs (52% Lean Yield)- with 44% or 47% SBM
11. Finishing Pigs (54% Lean Yield)- with 44% or 47% SBM

Table 5. Nutrient content of ingredients used to formulate the recommended growing-finishing diets (U of IL)
(% or amount/kg of diet)

Nutrient	Corn	High Oil Corn	Dehulled soybean meal	Regular soybean meal	FAT	L-lysine	DiCalcium Phosphate	Limestone
Protein, %	8.00	8.50	47.00	44.00				
Lysine, %	0.24	0.28	2.90	2.67		78.6		
Threonine, %	0.29	0.32	1.84	1.72				
Tryptophan, %	0.06	0.066	0.64	0.59				
Methionine, %	0.17	0.19	0.66	0.62				
Cystine, %	0.18	0.19	0.71	0.66				
Met. + Cys., %	0.35	0.38	1.37	1.28				
Calcium, %	0.03	0.03	0.20	0.30			22.0	38.0
Phosphorus, %	0.28	0.28	0.65	0.65			18.5	
Avail. Phos., %	0.042	0.042	0.160	0.247				
ME, kcal/kg	3420	3490	3385	3200	8875			
Crude Fat, %	3.60	6.42	1.00	1.00				
Crude Fiber, %	2.30	2.30	3.40	7.30				

July 25, 1996

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Nordstrom, J. W., B. R. Behrends, R. J. Meade and E. H. Thompson. 1972. Effect of feeding high-oil corns to growing-finishing swine. J. Animal Sci. 35:357-361.

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University of Illinois Recommended Dietary Formulations GESTATION Diets CORN/44% SBM HIGH-OIL CORN/44% SBM		
	Gestation w/44% SBM	High Oil Corn Gestation w/44% SBM
Corn	1631.73	
High Oil Corn		1649.75
SBM (44%)	**292**	**269**
Dicalcium Phosphate	40.71	44.49
Limestone	20.20	20.29
Salt	10	10.4
Gest/Lact Vitamin Premix	3.0	3.12
Gest/Lact Trace Mineral Premix	1.5	1.56
L-Lysine HCl	0.86	1.39
Total Weight	**2000**	**2000**
Crude Protein, %	12.99	13.00
Lysine, %	**0.62**	**0.64**
Threonine, %	0.49	0.49
Tryptophan, %	0.13	0.13
Methionine, %	0.23	0.24
Meth + Cys, %	0.47	0.48
Crude Fat, %	3.08	5.43
Crude Fiber, %	2.94	2.88
Calcium, %	0.90	0.94
Phosphorus-Total	0.70	0.73
Phosphorus-Available	0.446	0.478
M.E., k cal/lb.	1481	1537

November 22, 1996

University of Illinois Recommended Dietary Formulations GESTATION Diets CORN/47% SBM HIGH-OIL CORN/47% SBM		
	Gestation w/47% SBM	High Oil Corn Gestation w/47% SBM
Corn	1652.77	
High Oil Corn		1668.87
SBM (47%)	**270**	**249**
Dicalcium Phosphate	41.17	44.92
Limestone	20.81	20.84
Salt	10	10.4
Gest/Lact Vitamin Premix	3.0	3.12
Gest/Lact Trace Mineral Premix	1.5	1.56
L-Lysine HCl	0.75	1.29
Total Weight	**2000**	**2000**
Crude Protein, %	12.99	13.01
Lysine, %	**0.62**	**0.64**
Threonine, %	0.49	0.49
Tryptophan, %	0.13	0.13
Methionine, %	0.23	0.24
Meth + Cys, %	0.47	0.49
Crude Fat, %	3.11	5.48
Crude Fiber, %	2.36	2.34
Calcium, %	0.90	0.94
Phosphorus-Total	0.70	0.73
Phosphorus-Available	0.435	0.469
M.E., k cal/lb.	1493	1548

November 22, 1996

University of Illinois Recommended Dietary Formulations
LACTATION Diets
CORN/44% SBM
CORN/44% SBM + 3% Fat
HIGH-OIL CORN/44% SBM

	Lactation w/44% SBM	Lactation w/44% SBM + 3% Fat	High Oil Corn Lactation w/44% SBM
Corn	1468.52	1377.23	
High Oil Corn			1476.32
SBM (44%)	**457**	**484**	**437**
Fat		60	7.0
Dicalcium Phosphate	37.40	41.06	41.22
Limestone	20.95	20.79	20.99
Salt	10	10.4	10.4
Gest/Lact Vitamin Premix	3.0	3.12	3.12
Gest/Lact Trace Mineral Premix	1.5	1.56	1.56
L-Lysine HCl	1.63	1.84	2.39
Total Weight, lbs.	**2000**	**2000**	**2000**
Crude Protein, %	16.01	16.24	16.00
Lysine, %	**0.85**	**0.88**	**0.88**
Threonine, %	0.60	0.61	0.61
Tryptophan, %	0.18	0.18	0.18
Methionine, %	0.27	0.27	0.27
Meth + Cys, %	0.55	0.55	0.56
Crude Fat, %	2.87	5.69	5.30
Crude Fiber, %	3.36	3.35	3.29
Calcium, %	0.90	0.94	0.94
Phosphorus-Total	0.70	0.73	0.73
Phosphorus-Available	0.43	0.47	0.46
M.E., k cal/lb.	1475	1532	1532

November 22, 1996

University of Illinois Recommended Dietary Formulations
LACTATION Diets
CORN/47% SBM
CORN/47% SBM + 3% Fat
HIGH-OIL CORN/47% SBM

	Lactation w/47% SBM	Lactation w/47% SBM + 3% Fat	High Oil Corn Lactation w/47% SBM
Corn	1502.03	1419.30	
High Oil Corn			1506.89
SBM (47%)	**422**	**440**	**404**
Fat		60	8.0
Dicalcium Phosphate	38.11	41.97	41.92
Limestone	21.90	21.74	21.89
Salt	10	10.40	10.40
Gest/Lact Vitamin Premix	3.0	3.12	3.12
Gest/Lact Trace Mineral Premix	1.5	1.56	1.56
L-Lysine HCl	1.46	1.91	2.22
Total Weight, lbs	**2000**	**2000**	**2000**
Crude Protein, %	15.99	16.11	16.00
Lysine, %	**0.85**	**0.88**	**0.88**
Threonine, %	0.60	0.61	0.61
Tryptophan, %	0.18	0.18	0.18
Methionine, %	0.27	0.26	0.28
Meth + Cys, %	0.55	0.55	0.56
Crude Fat, %	2.91	5.74	5.44
Crude Fiber, %	2.44	2.38	2.42
Calcium, %	0.90	0.94	0.94
Phosphorus-Total	0.70	0.73	0.73
Phosphorus-Available	0.42	0.452	0.45
M.E., k cal/lb	1494	1551	1551

November 22, 1996

University of Illinois Recommended Dietary Formulations STARTER 1 Diets CORN/47% SBM HIGH-OIL CORN/47% SBM		
	Starter 1 9-15 lbs	High Oil Corn Starter 1 9-15 lbs
Corn	955.69	
High Oil Corn		1016.87
Whey	400	400
SBM (47%)	**290**	**269**
Plasma Protein	150	150
Soybean Oil	100	60.00
Monocalcium phosphate	38.57	38.41
Blood Meal	35	35
Limestone	18.36	18.49
Vitamin Premix	4.0	4.0
DL-Methionine	2.61	2.38
Copper Sulfate	2.0	2.0
Trace-mineral Premix	2.0	2.0
L-Lysine HCl	1.77	1.85
Total Weight	**2000**	**2000**
Crude Protein, %	20.00	20.01
Lysine, %	**1.40**	**1.40**
Threonine, %	0.94	0.95
Tryptophan, %	0.28	0.28
Methionine, %	0.40	0.40
Meth + Cys, %	0.84	0.84
Crude Fat, %	7.13	6.71
Crude Fiber, %	1.63	1.66
Lactose, %	**13.80**	**13.80**
Calcium, %	0.90	0.90
Phosphorus-Total	0.80	0.80
M.E. k cal/lb.	1599	1599

November 22, 1996

University of Illinois Recommended Dietary Formulations STARTER 2 Diets CORN/47% SBM HIGH-OILCOR/47% SBM		
	Starter 2 15-25 lbs	High Oil Corn - Starter 2 15-25 lbs
Corn	810.87	
High Oil Corn		857.01
Oats	400	400
Whey	300	300
SBM (47%)	**241**	**224**
Menhaden Fish Meal	150	150
Fat	60	31
Dicalcium phosphate	14.18	14.07
Limestone	8.94	9.05
Salt	5.0	5.0
Vitamin Premix	4.0	4.0
DL-Methionine	0.67	0.48
Copper Sulfate	2.0	2.0
Trace-mineral Premix	1.5	1.5
L-Lysine HCl	1.84	1.89
Total Weight	**2000**	**2000**
Crude Protein, %	18.50	18.49
Lysine, %	**1.15**	**1.15**
Threonine, %	0.75	0.7547
Tryptophan, %	0.29	0.2900
Methionine, %	0.39	0.39
Meth + Cys, %	0.69	0.6899
Crude Fat, %	6.68	6.53
Crude Fiber, %	2.07	2.09
Lactose, %	**10.35**	**10.35**
Calcium, %	0.85	0.85
Phosphorus-Total	0.75	0.75
M.E. k cal/lb.	1590	1590

November 22, 1996

University of Illinois Recommended Dietary Formulations
STARTER 3 Diets
CORN/47% SBM
CORN/47% SBM + 3% Fat
HIGH-OIL CORN/47% SBM

	Starter 3 25-50 lbs	Starter 3 w/3% fat 25-50 lbs	High Oil Corn Starter 3 25-50 lbs
Corn	1460.05	1345.67	
High Oil Corn			1454.13
SBM (47%)	**470**	**522**	**462**
Fat		60	10
Dicalcium phosphate	37.06	40.21	40.66
Limestone	17.02	16.59	16.56
Salt	7.0	7.0	7.0
Vitamin Premix	3.0	3.1	3.1
Copper Sulfate	2.0	2.0	2.0
Trace-mineral Premix	1.5	1.6	1.6
L-Lysine HCl	2.37	1.83	2.95
Total Weight	**2000**	**2000**	**2000**
Crude Protein, %	17.00	17.74	17.18
Lysine, %	**0.95**	**0.99**	**0.99**
Threonine, %	0.64	0.67	0.66
Tryptophan, %	0.19	0.21	0.20
Methionine, %	0.28	0.29	0.29
Meth + Cys, %	0.58	0.59	0.59
Crude Fat, %	2.86	5.65	5.39
Crude Fiber, %	2.48	2.43	2.46
Calcium, %	0.80	0.83	0.83
Phosphorus-Total	0.70	0.73	0.73
M.E., k cal/lb.	1499	1557	1557

November 22, 1996

University of Illinois Recommended Dietary Formulations for GROWING Pigs Fed HIGH OIL CORN and 44% or 47%Soybean Meal

(50% Lean Yield, 1.0" backfat for barrows)

(50% lean yield, 0.9" backfat for gilts)

SEX:	Barrows &Gilts				Barrows & Gilts			
Weight Range, lbs	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**
HIGH OIL CORN					1501.93	1563.57	1527.69	1590.39
Soybean Meal (44%)					429	372	---------	--------
Soybean Meal (47%)					----------	----------	400	343
FAT					5	4	7	5
DiCalcium Phosphate					32.5	28.1	33.1	28.7
Limestone					16.1	16.4	17	17.1
White Salt					8	8	8	8
L-Lysine (98%)					**2.97**	**3.43**	**2.71**	**3.31**
Trace Mineral Premix					2.5	2.5	2.5	2.5
Vitamin Premix					2	2	2	2
TOTAL, LBS					**2000**	**2000**	**2000**	**2000**
Crude Protein, %					15.96	14.99	16.02	14.98
Calcium, %					.75	.70	.75	.70
Phosphorus, %					.65	.60	.65	.60
Avail. Phosphorus, %					.38	.34	.37	.33
Crude Fat, %					5.28	5.40	5.45	5.52
Crude Fiber, %					3.29	3.16	2.44	2.41
LYSINE, %					**.90**	**.85**	**.90**	**.85**
Tryptophan, %					.176	.161	.178	.162
Threonine, %					.609	.570	.612	.570
Meth. + Cys, %					.560	.535	.564	.537
M.E., Kcal/kg					3404	343419	3448	3456
M.E., Kcal/lb					1544	1551	1564	1568

May 15, 1996

University of Illinois Recommended Dietary Formulations for GROWING Pigs Fed HIGH OIL CORN and 44% or 47%Soybean Meal (52% Lean Yield, 0.9" backfat for barrows) (52% lean yield, 0.8" backfat for gilts)

SEX:	Barrows &Gilts				Barrows & Gilts			
Weight Range, lbs	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**
HIGH OIL CORN					1437.69	1514.66	1478.86	1549.14
Soybean Meal (44%)					492	421	---------	--------
Soybean Meal (47%)					----------	----------	448	383
FAT					8	5	9	7
DiCalcium Phosphate					31.2	27.2	32.1	27.9
Limestone					16.4	16.6	17.3	17.4
White Salt					8	8	8	8
L-Lysine (98%)					**2.21**	**3.04**	**2.24**	**3.06**
Trace Mineral Premix					2.5	2.5	2.5	2.5
Vitamin Premix					2	2	2	2
TOTAL, LBS					**2000**	**2000**	**2000**	**2000**
Crude Protein, %					17.04	15.84	16.92	15.73
Calcium, %					.75	.70	.75	.70
Phosphorus, %					.65	.60	.65	.60
Avail. Phosphorus, %					.38	.34	.36	.32
Crude Fat, %					5.26	5.32	5.42	5.51
Crude Fiber, %					3.45	3.28	2.46	2.43
LYSINE, %					**.945**	**.893**	**.945**	**.893**
Tryptophan, %					.193	.174	.192	.174
Threonine, %					.653	.604	.649	.600
Meth. + Cys, %					.588	.557	.588	.557
M.E., Kcal/kg					3399	3413	3448	3456
M.E., Kcal/lb					1542	1548	1564	1568

May 15, 1996

University of Illinois Recommended Dietary Formulations for GROWING Pigs Fed HIGH OIL CORN and 44% or 47%Soybean Meal

(54% Lean Yield, 0.8" backfat for barrows)

(54% lean yield, 0.7" backfat for gilts)

SEX:	Barrows &Gilts				Barrows & Gilts			
Weight Range, lbs	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**	**40-80**	**80-120**
HIGH OIL CORN					1387.73	1421.64	1433.60	1467.67
Soybean Meal (44%)					541	512	---------	--------
Soybean Meal (47%)					----------	----------	493	465
FAT					10	10	10	9
DiCalcium Phosphate					30.3	25.4	31.3	26.3
Limestone					16.6	17	17.7	18
White Salt					8	8	8	8
L-Lysine (98%)					**1.87**	**1.46**	**1.90**	**1.53**
Trace Mineral Premix					2.5	2.5	2.5	2.5
Vitamin Premix					2	2	2	2
TOTAL, LBS					**2000**	**2000**	**2000**	**2000**
Crude Protein, %					17.89	17.37	17.77	17.24
Calcium, %					.75	.70	.75	.70
Phosphorus, %					.65	.60	.65	.60
Avail. Phosphorus, %					.38	.33	.36	.31
Crude Fat, %					5.22	5.31	5.34	5.39
Crude Fiber, %					3.57	3.50	2.49	2.48
LYSINE, %					**.99**	**.94**	**.99**	**.94**
Tryptophan, %					.205	.198	.205	.197
Threonine, %					.687	.668	.683	.663
Meth. + Cys, %					.610	.598	.610	.597
M.E., Kcal/kg					333395	3408	3448	3456
M.E., Kcal/lb					1540	1546	1564	1568

May 15, 1996

University of Illinois Recommended Dietary Formulations for FINISHING Pigs Fed HIGH-OIL CORN and 44% Soybean Meal (50% Lean Yield Yield, 1.0" backfat for barrows) (50% Lean Yield, 0.9" backfat for gilts)

SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1637.34	1698.62	1779.64	1681.60	1722.82	1779.89	1601.26	1688.84	1751.88
SBM (44%)	306	251	174	263	227	174	342	261	203
Fat	2	0	0	0	0	0	3	0	0
DiCal (18.5%P)	23.9	20	16	24.8	20	16	23.2	19.3	15.0
Limestone	16.7	16.7	16.9	16.5	16.8	16.9	16.8	17.0	17.3
White Salt	8	8	8	8	8	8	8	8	8
L-lysine HCL	2.86	2.48	2.26	2.90	2.18	2.01	2.54	2.66	1.62
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Crude Prot.,%	13.83	12.86	11.50	13.07	12.42	11.49	14.45	13.05	11.99
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail P, %	0.29	0.25	0.20	0.30	0.25	0.20	0.29	0.25	0.20
Crude Fat, %	5.51	5.58	5.80	5.53	5.64	5.80	5.46	5.55	5.73
Cr. Fiber, %	3.00	2.87	2.68	2.89	2.81	2.68	3.09	2.89	2.76
LYSINE, %	**0.75**	**0.67**	**0.57**	**0.70**	**0.63**	**0.56**	**0.78**	**0.69**	**0.58**
Tryptophan, %	0.144	0.13	0.11	0.13	0.123	0.11	0.15	0.13	0.11
Threonine, %	0.525	0.487	0.434	0.495	0.471	0.434	0.550	0.494	0.455
Meth. + Cys, %	0.507	0.483	0.449	0.487	0.472	0.449	0.523	0.487	0.463
M.E., Kcal/kg	3436	3449	3470	3439	3453	3470	3432	3448	3466
M.E., Kcal/lb	1559	1565	1574	1560	1566	1574	1557	1564	1572

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SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1660.3	1719.92	1794.13	1706.47	1754.28	1794.40	1627.07	1719.41	1793.89
SBM (47%)	282	229	159	236	194	159	315	229	159
Fat	2	0	0	1	0	0	3	0	0
DiCal(18.5%P)	24.4	20	15.9	25.3	20.7	15.9	23.8	20	15.9
Limestone	17.3	17.4	17.5	17	17.2	17.5	17.5	17.4	17.5
White Salt	8	8	8	8	8	8	8	8	8
L-lysine HCl	2.77	2.48	2.26	3.03	2.62	2.00	2.43	2.99	2.51
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Crude Prot.,%	13.81	12.81	11.47	12.94	12.14	11.46	14.43	12.83	11.48
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail . P, %	0.28	0.24	0.20	0.28	0.24	0.20	0.28	0.24	0.20
Crude Fat, %	5.57	5.64	5.84	5.65	5.73	5.84	5.53	5.63	5.84
Cr. Fiber, %	2.39	2.37	2.33	2.36	2.35	2.33	2.41	2.37	2.33
LYSINE, %	**0.75**	**0.67**	**0.57**	**0.70**	**0.63**	**0.56**	**0.78**	**0.69**	**0.58**
Tryptophan, %	0.145	0.13	0.11	0.13	0.12	0.11	0.15	0.13	0.11
Threonine, %	0.525	0.485	0.43	0.490	0.459	0.433	0.55	0.485	0.433
Meth. + Cys, %	0.508	0.484	0.45	0.485	0.466	0.45	0.525	0.483	0.450
M.E., Kcal/kg	3465	3473	3487	3466	3476	3487	3465	3474	3487
M.E., Kcal/lb	1572	1575	1582	1572	1576	1582	1572	1575	1582

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University of Illinois Recommended Dietary Formulations for FINISHING Pigs Fed HIGH-OIL CORN and 44% Soybean Meal (52% Lean Yield Yield, 0.9" backfat for barrows) (52%-53% Lean Yield, 0.8" backfat for gilts)

SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1601.01	1686.63	1741.96	1644.27	1714.29	1748.81	1573.61	1659.31	1734.82
SBM (44%)	342	263	213	299	235	206	370	289	220
Fat	3	0	0	2	0	0	3	2	0
DiCal(18.5%P)	23.2	19.3	14.8	24.1	19.9	14.9	22.6	18.8	14.7
Limestone	16.8	17	17.3	16.6	16.9	17.3	16.9	17.1	17.4
White Salt	8	8	8	8	8	8	8	8	8
L-Lysine	2.79	2.87	1.84	2.83	2.71	1.79	2.69	2.59	1.88
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
C.P, %	14.46	13.09	12.18	13.70	12.58	12.05	14.95	13.53	12.30
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail P, %	0.29	0.245	0.20	0.29	0.245	0.20	0.29	0.243	0.20
Crude Fat, %	5.46	5.55	5.70	5.53	5.62	5.72	5.38	5.57	5.68
Cr. Fiber, %	3.09	2.90	2.78	2.98	2.83	2.76	3.16	2.96	2.80
LYSINE, %	**0.79**	**0.70**	**0.60**	**0.74**	**0.66**	**0.59**	**0.82**	**0.72**	**0.61**
Tryptophan, %	0.15	0.13	0.12	0.14	0.13	0.12	0.16	0.14	0.12
Threonine, %	0.550	0.496	0.462	0.520	0.476	0.457	0.570	0.514	0.467
Meth. + Cys, %	0.523	0.489	0.467	0.504	0.476	0.464	0.536	0.500	0.470
M.E., Kcal/kg	3433	3448	3464	3437	3452	3465	3428	3448	3464
M.E., Kcal/lb	1557	1564	1571	1559	1566	1572	1555	1564	1571

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SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1625.82	1708.61	1780.05	1667.27	1736.40	1786.13	1598.23	1683.21	1760.79
SBM (47%)	315	239	173	275	212	167	342	264	193
Fat	4	1	0	2	0	0	5	2	0
DiCal(18.5%P)	23.8	19.8	15.6	24.6	20.3	15.7	23.3	19.3	15.2
Limestone	17.5	17.5	17.6	17.2	17.3	17.5	17.7	17.7	17.7
White Salt	8	8	8	8	8	8	8	8	8
L-lysine HCl	2.68	2.89	2.55	2.73	2.80	2.47	2.57	2.59	2.11
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
C.P, %	14.44	13.01	11.75	13.68	12.49	11.63	14.95	13.48	12.12
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail P, %	0.28	0.24	0.19	0.28	0.24	0.19	0.28	0.23	0.19
Crude Fat, %	5.57	5.65	5.80	5.59	5.68	5.82	5.55	5.63	5.75
Cr. Fiber, %	2.41	2.37	2.34	2.38	2.36	2.34	2.42	2.38	2.35
LYSINE, %	**0.79**	**0.70**	**0.60**	**0.74**	**0.66**	**0.59**	**0.82**	**0.72**	**0.61**
Tryptophan, %	0.15	0.13	0.11	0.14	0.125	0.11	0.16	0.14	0.12
Threonine, %	0.550	0.493	0.444	0.520	0.473	0.439	0.570	0.512	0.459
Meth. + Cys, %	0.525	0.488	0.456	0.505	0.475	0.454	0.538	0.500	0.466
M.E., Kcal/kg	3467	3475	3486	3467	3475	3486	3467	3475	3486
M.E., Kcal/lb	1572	1576	1581	1572	1576	1581	1572	1576	1581

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University of Illinois Recommended Dietary Formulations for FINISHING Pigs Fed HIGH-OIL CORN and 44% Soybean Meal (54% Lean Yield Yield, 0.8" backfat for barrows) (54% Lean Yield, 0.7" backfat for gilts)

SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1559.02	1651.16	1721.04	1615.88	1691.65	1722.28	1518.93	1636.38	1720.80
SBM (44%)	384	297	234	327	258	233	424	312	234
Fat	4	2	0	3	0	0	5	2	0
DiCal(18.5%P)	22.4	18.6	14.4	23.5	19.4	14.4	21.6	18.3	14.4
Limestone	17	17.2	17.4	16.7	17	17.4	17.2	17.2	17.4
White Salt	8	8	8	8	8	8	8	8	8
L-lysine HCl	2.38	2.84	1.96	2.72	2.75	1.72	2.07	2.92	2.20
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
C.P, %	15.19	13.69	12.55	14.19	13.00	12.53	15.88	13.96	12.57
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail P, %	0.29	0.24	0.20	0.29	0.25	0.20	0.28	0.24	0.20
Crude Fat, %	5.39	5.55	5.64	5.50	5.56	5.65	5.34	5.51	5.64
Cr. Fiber, %	3.19	2.98	2.83	3.05	2.89	2.83	3.29	3.02	2.83
LYSINE, %	**0.825**	**0.74**	**0.63**	**0.77**	**0.69**	**0.62**	**0.86**	**0.76**	**0.64**
Tryptophan, %	0.16	0.14	0.125	0.15	0.13	0.125	0.17	0.146	0.125
Threonine, %	0.580	0.520	0.477	0.540	0.492	0.476	0.608	0.530	0.476
Meth. + Cys, %	0.542	0.504	0.477	0.516	0.486	0.476	0.560	0.510	0.476
M.E., Kcal/kg	3428	3447	3461	3435	3447	3461	3424	3445	3461
M.E., Kcal/lb	1555	1564	1570	1558	1564	1570	1553	1562	1570

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SEX:	Barrows &Gilts			Barrows			Gilts		
Wt. lb	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**	**120-160**	**160-210**	**210-260**
High Oil Corn	1586.74	1673.15	1759.28	1639.78	1719.41	1759.73	1554.31	1660.28	1753.26
SBM (47%)	354	274	194	302	229	194	386	287	200
Fat	5	2	0	3	0	0	6	2	0
DiCal(18.5%P)	23	19.1	15.2	24	20	15.2	22.4	18.8	15.1
Limestone	17.8	17.8	17.7	17.4	17.4	17.7	18	17.9	17.8
White Salt	8	8	8	8	8	8	8	8	8
L-lysine HCl	2.26	2.75	2.62	2.62	2.99	2.37	2.09	2.82	2.64
Vitamin Premix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TM Premix	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
TOTAL, LBS	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**	**2000**
Cr. Protein, %	15.17	13.68	12.16	14.19	12.83	12.15	15.78	13.93	12.28
Calcium, %	0.65	0.60	0.55	0.65	0.60	0.55	0.65	0.60	0.55
Phosphorus,%	0.55	0.50	0.45	0.55	0.50	0.45	0.55	0.50	0.45
Avail P, %	0.27	0.23	0.19	0.28	0.24	0.19	0.27	0.23	0.19
Crude Fat, %	5.52	5.61	5.74	5.56	5.63	5.75	5.48	5.57	5.73
Cr. Fiber, %	2.43	2.39	2.35	2.40	2.37	2.35	2.44	2.40	2.36
LYSINE, %	**0.824**	**0.74**	**0.63**	**0.77**	**0.69**	**0.62**	**0.86**	**0.76**	**0.64**
Tryptophan, %	0.165	0.14	0.12	0.15	0.13	0.12	0.17	0.146	0.12
Threonine, %	0.580	0.520	0.460	0.540	0.485	0.460	0.604	0.530	0.464
Meth. + Cys, %	0.544	0.505	0.467	0.518	0.483	0.467	0.560	0.512	0.470
M.E., Kcal/kg	3466	3475	3485	3466	3475	3485	3466	3475	3485
M.E., Kcal/lb	1572	1576	1581	1572	1576	1581	1572	1576	1581

May 15, 1996

Alternative Feedstuffs for Swine Deits

by
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Pigs need energy for maintenance, growth, reproduction and/or lactation. In Illinois, and throughout the Midwest, corn is used almost extensively as the energy source in swine diets. Many other cereal grains are excellent energy sources for swine diets. These include, sorghum (milo), wheat , barley, oats and their by-products. The overall value of wheat or sorghum as an alternative grain has to include the relative value of each grain on the basis of energy content and protein as well as amino acid content. For instance, wheat is normally higher in crude protein and amino acid content than corn or sorghum, thus the relative value of wheat depends to some extent on the price of soybean meal and other protein supplements.

Fat, which contains 2.25 times the amount of energy as cereal grains is often used to increase the energy density of swine diets. The energy content of feedstuffs and energy requirements of pigs are commonly expressed as metabolizable energy (ME). Most common cereal grains and fats are very palatable and digestible. Cereal by-products tend to be more variable; therefore their use in swine diets may be limited. With today's corn prices, producers may find other energy sources attractive for inclusion in swine diets.

When evaluating alternative energy sources, a producer should focus on the relative feeding value of energy sources when compared to corn (Table 1) rather than on achieving certain feed efficiency or growth rate. Substituting grain sorghum for corn, for example, will likely reduce feed efficiency, but possibly reduce the cost of gain also. The feeding values were calculated using the ME, digestible lysine, and available phosphorus content of feedstuffs. Corn, soybean meal (44% CP), and dicalcium phosphate were used as reference feedstuffs. Corn is assumed to have a feeding value of 100%. Grain sorghum, for example, has a feeding value of about 95% that of corn. Thus, grain sorghum can replace corn in the diet when the price of grain sorghum is less than 95 % of the price of the same weight of corn. Thus, if the grain sorghum is $.07125/pound or less, it is a better buy than corn that costs $075/pound ($4.20/bushel).

The relative feeding values apply when ingredients are included in diets in quantities no greater than those shown in Table 1. When ingredients are included in diets at lower levels than indicated in Table 1, the feeding value may increase slightly. Average daily gain and reproductive performance will not normally be reduced by replacing corn with any of the energy sources at the levels shown in Table 1. A range in feeding value is presented to account for variation in ingredient quality and individual producer goals. Also, when considering the economics of using one of these alternative energy sources, be sure to consider factors such as storage costs and ingredient quality and availability. When using one of these alternative energy sources it would be best to reformulate the diet on a total or digestible lysine basis. Do not formulate diets on a protein basis because the diet

may then be deficient in lysine, resulting in reduced pig performance. One advantage of formulating on a lysine basis is that the additional protein in wheat or barley, for example, can be taken advantage of. This means less supplemental protein is needed in the diet. Another method would be to substitute the alternative energy source for corn on a pound-for-pound basis in the diet. This procedure is acceptable for all energy sources in Table 1, except for fats, oils and potatoes (22% D.M.). Fats and oils contribute no protein or amino acids to the diet. Thus, the diet must be reformulated.

As noted above, the four major cereal grains used to replace corn in swine diets in the Midwest are grain sorghum (milo), wheat, barley and oats. The energy content of grain sorghum is slightly lower than corn, thus feed efficiency will be slightly less when milo replaces corn in the diet. One disadvantage of grain sorghum is that it is that it can be more variable in nutrient content than corn because of growing conditions. In addition, because a grain sorghum kernel is smaller and harder than a corn kernel, fine grinding, (1/8 or 5/32" screen) or rolling is suggested for best utilization.

Because wheat has slightly more lysine and phosphorus than corn and grain sorghum, the amount of soybean meal and dicalcium phosphate can be reduced in the diet. Research shows that soft red winter wheat is comparable in feeding value to hard red winter wheat for finishing pigs. Because wheat tends to flour when processed, it should be coarsely ground (3/16" screen) or rolled. If ground too finely, feed intake may be decreased and performance lowered.

Barley contains more lysine than corn, but less energy and more fiber. Therefore, pigs fed barley-based diets will tend to have 5 to 10 percent poorer feed efficiency. Fine grinding (600 to 700 microns) of barley diets improves the feeding value for growing-finishing pigs, but when energy intake is critical, barley diets are not recommended.

Oats have more lysine than corn, but their high fiber content limits their application in swine diets. Oats should not exceed 30 percent of the diet for growing-finishing pigs. Because of the high fiber content of oats and barley, they may be best used in sow gestation diets, if economically priced.

Where to Use Alternatives

There truly is more to making decisions to switch grain sources (feedstuffs) than cost and formulating a new diet. Alternatives include various small grains, fats and byproducts. The suitability of these products is dependent on location, price and availability to the producer.

Wheat, barley, sorghum grain (milo), oats and possibly rye are small grains that may be available. Fat sources may be competitive with high-priced corn. Byproduct feeds are another option often available to producers on a limited basis. Each alternative feedstuff has different values for various stages of production. I would suggest that diets for young pigs (starter pigs) should receive priority usage of limited corn supplies. The attached table (Table 2) indicates the maximum levels at which each of the grains or byproducts can be added to a swine diet and still maintain performance. The table also lists the relative value of each feed alternative compared to corn.

Economics of Alternatives

Use of alternative feedstuffs needs to be calculated on more than a mere feed cost/ton basis. Before using alternative ingredients, producers need to consider the impact the new ingredient may have on feed efficiency. A simple way to estimate the impact of an alternative ingredient on feed efficiency is to look at the metabolizable energy content of a ration. Below is a way to compare feed efficiency numbers when evaluating alternative ingredients.

Comparing Feed Efficiency Numbers When Evaluating Alternative Ingredients (Source: Mark Newcomb, Extension Swine Specialist, University of Missouri):

Step 1: ME of normal ration ÷ ME of alternative ration = % of ME in new ration versus the old ration.

Step 2: Expected feed efficiency with a new ration = FE with normal ration ÷ % of ME in new ration versus the old ration

For example: If the normal ration contains 3250 kcal/kg of ME and the old ration with an alternative feedstuffs calculates to 3100 kcal/kg of ME, then:

3250 kcal/kcal ME ÷ 3100 kcal/kg ME = New ration only has 95.4% of ME of the normal ration

So if feed efficiency with the normal ration is 3.1, expected feed efficiency with the new ration is calculated:

3.1 lb. feed/lb. gain ÷ 95.4% = 3.26 FE expected with the new ration.

This means that 0.16 more lb. of feed/lb. of gain would be used than with the normal ration.

Table 1. Feeding Value of Energy Feeds Compared to Corn[1]

Feedstuff	Relative Feeding Value compared to corn, %[2]	Maximum recommended percent of complete diets		
		Gestation	Lactation	Grower-Finisher
Corn	100	90	80	90
Alfalfa meal, dehydrated	65-75	10	0	5
Bakery waste, surplus materia	95-110	40	40	40
Barley (48 lb/bushel)	90-95	80	80	85
Brewers dried grains	90-100	40	5	10
Buckwheat	80-90	50	0	50
Fat and oil (stabilized)	190-200	5	5	5
Grain sorghum, milo (>48 lb/bu)	95	80	80	85
Hominy (Corn grits by-product)	100-15	60	60	60
High lysine corn	100-110	90	80	90
Millet, proso	85-95	80	40	85
Oats (38 lb/bu)	85-95	80	10	30
Potatoes (22% D.M.)	20-25	80	0	30
Rye	85-95	20	10	25
Triticale	95-105	60	60	60
Wheat, hard (>55 lb/bu)	100-110	80	80	85
Wheat, soft	90-95	80	80	85
Wheat middlings	110-120	30	10	25

[1]Based on air dry basis unless otherwise noted.

[2]When fed at no more than maximum recommended percent of complete diets. Relative values based on metabolizable energy, lysine and phosphorus content using simultaneous equations.

Table 2. Ingredient inclusion levels that have produced satisfactory results and their relative values.[a]

Ingredient	Percentage of following diets				Relative value vs.[b]		Remarks
			Stage of development				
	Gestation	Lactation	6-30 lbs	30-280 lbs	Corn	SBM, dehulled	
Alfalfa meal, dehydrated	0-50	0-10	0	0-5	80-100	30	Low energy, high fiber, carotene
Animal fat, stabilized	0-8	0-8	0-8	0-8	140-160		High energy, more than 5% may bridge feed
Barley[c]	0-90	0-85	0-25	0-95	100-105		Energy source, moderate fiber
Beet pulp, dried	0-10	0-10	0	0	90-105		Bulky, high fiber, laxative
Blood meal, spray	0-5	0-5	0-5	0-5		205-220	High lysine, low isoleucine and tryptophan
Canola meal, solvent	0-5	0-5	0	0-5		72-74	High fiber
Corn, yellow[c]	0-90	0-85	0-45	0-95	100		Energy source, low lysine and tryptophan
Corn, yellow, high oil	0-90	0-85	0-45	0-85	105		Energy source, low lysine and tryptophan
Corn distillers dried grain w/solubles	0-10	0-5	0-5	0-5		45-50	B vitamin source, low lysine
Corn gluten feed	0-90	0	0	0	110-130	40-50	Low lysine and tryptophan availability
Corn gluten meal, 60% CP	0-5	0-5	0	0-5		55-65	Low lysine and tryptophan availability
Cottonseed meal, solvent	0-5	0-5	0	0-5		64-68	Gossypol toxicity, low lysine
Fish meal, menhaden	0-10	0-10	0-10	0-5		165-170	Potential rancidity
Fish solubles, condensed	0-5	0-5	0-5	0-3		65	Approximately 5% salt
Hominy feed	0-60	0-60	0	0-60	100-105		Energy source
Lactose	0	0	0-20	0	85-95		Energy source, palatable
Meat and bone meal	0-10	0-5	0-5	0-5		108-115	Low tryptophan, high calcium and phosphorus
Molasses, cane	0-5	0-5	0-5	0-5	34-38		Palatable
Oats	0-90	0-15	0	0-20	80-85		Energy source, high fiber
Oat groats (dehulled oats)	0-30	0-30	0-30	0-30	115-125		Energy source, palatable
Plasma protein, spray dried	0	0	0-8	0		205-215	Immunoglobulins, high salt content
Poultry byproduct meal	0-5	0-5	0	0-5		136-139	Potential of high ash content
Skim milk, dried	0	0	0-20	0		100-105	Excellent amino acid balance, palatable
Sorghum, grain[b]	0-90	0-85	0-45	0-95	92		Energy source, low lysine and tryptophan
Soybean meal, dehulled, solvent[b]	0-10	0-25	0-45	0-40		100	Good amino acid balance with corn
Soybean meal, solvent[b]	0-12	0-30	0-48	0-45		96	Good amino acid balance with corn
Soybeans, full-fat, cooked	0-15	0-32	0-60	0-50		90-100	High energy, soft pork
Soybean oil	0-8	0-8	0-8	0-8	190-215		High energy, more than 5% may bridge feed
Sugar (sucrose)	0	0	0-5	0	95-105		Added for palatability
Sunflower meal, 28% CP	0-10	0	0	0-10		45-55	High fiber, low lysine
Wheat, hard[c]	0-90	0-85	0-45	0-95	110-115		Energy source, low fiber
Wheat bran	0-30	0-10	0	0-5	95-105		High fiber, laxative
Wheat midds	0-30	0-20	0-5	0-5	95-115		Low energy, partial grain substitute
Whey, dried	0-5	0-5	0-30	0-5	130-160		Excellent amino acid bal., palatable, high salt content
Whey, dried, delactosed	0-5	0-5	0-30	0-5	140-200		Excellent amino acid bal., palatable, high salt content
Yeast, Dried brewers	0-3	0-3	0-3	0-3		112-115	Source of B-vitamins

[a]FROM: ISU Pub. PM-489 (7/96)

[b]Relative value considers lysine, net energy and available phosphorus contents. The relative cost of an ingredient can be evaluated by comparing its cost with the cost of corn or dehulled soybean meal times the particular coefficient for the relative value of the ingredient compared to corn or soybean meal. These values assume feeding levels within the suggested limits. High fiber feeds will decrease in value as their level in the feed is increased.

[c]Corn, barley, sorghum or wheat should be the basic energy source with other substitutions made within the ranges suggested. Soybean meal is assumed to be the basic protein source with other substitutions made within the ranges suggested.

Effects of Pork Feed Processing on Feed Efficiency

by
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Cereal grains are the primary energy source in swine diets. Therefore, not only must producers be concerned about the composition of the grain, but also how it is processed so the pig may fully utilize the nutrients.

Since feed represents 65 to 75 percent of overall production costs in a swine operation, improving the efficiency of feed utilization will have a tremendous impact on the cost of production. Nearly all feed ingredients will be subjected to some type of particle size reduction.

Particle size reduction increases the surface area of the grain, thus allowing for greater interaction with digestive enzymes. It also improves the ease of handling and the mixing characteristics. However, fine grinding will increase the energy costs of feed processing and may result in feed bridging, dust problems, and increase the incidence of gastric ulcers in swine. Therefore, the increased costs of fine grinding must be offset by improved feed conversion.

Particle Size and Pig Performance

In the past, there has been confusion regarding the optimum particle size in swine diets. This was a result of broad generalizations classifying dietary particle size. In the past, terms like fine, medium, and coarse were used to define particle size. Recently, a more precise classification of determining particle size has been developed based on the mean geometric diameter of particles measured in microns and the geometric mean standard deviation of the particle p-1Xs or their distribution (ASAE 1973). These measurements allow more precise definition of particle size and allow us to make specific recommendations to optimize swine performance.

Complicating the data available on the effects of particle size on pig performance are the interactions between age of the pig, grain type, and particle size. In general, it appears the young pig does a better job of chewing its feed than growing-finishing hogs. The greatest potential for fine grinding to improve feed efficiency will be for finishing pigs. However, fine grinding or rolling will improve feed efficiency regardless of age.

A study conducted at Kansas State University demonstrates the effects of particle on starter pig performance, In the study, 192 pigs (initial weight 13 to 18 pounds) were fed either corn- or -sorghum-based diets (Table 1).

The grains were either processed through a hammer mill equipped with an 1/8-inch (539 to 624 microns) or 1/4-inch (722 to 877 microns) screen. Each grain was rolled either fine (822 to 885 microns) or coarse (1,147 to 1,217 microns) by adjusting the roller gap and feeding rate.

As expected, fine grinding or rolling reduced mean particle size of the diet. Although the differences in particle size did not affect average daily gain (ADG), feed efficiency (feed/gain) was improved by either fine grinding or rolling. By pooling the data across grain type and processing method and classifying it based only on particle size, the improved feed efficiency appears to be a result of improved nutrient digestibility (Table 2).

Recently, Healy et al., 1994 evaluated growth performance of pigs weaned at 21 days of age and fed starter diets in which the grain (corn and hard or soft endosperm milo) was ground to 900, 700, 500, or 300 microns (Table 3). These results confirm that reducing grain particle size had little improvement on ADG. Average daily feed intake (ADFI) decreased (linear, $P < .08$) as particle size decreased suggesting an optimum particle size between 500 and 700 microns.

Pigs fed grain ground to 500 microns had a percent improvement in feed efficiency compared to those pigs fed diets containing grain ground to 900 microns. However, production rate (tons of grain ground per hour) was reduced 43 percent by decreasing particle size from 700 to 500 microns. Also important is the numerical trend for decreased ADG and ADFI and poorer F/G of pigs fed the diets containing grain ground to 300 microns. The decision on optimum diet particle needs to include assessment of improvement in feed efficiency versus reductions in milling production. These and other data suggest a dietary particle size of approximately 700 microns to optimize both pig performance and milling efficiency.

Particle Size and Alternative Grains

The type of grain in the diet also will influence the pig's response to particle size reduction. Studies with high-fiber feed ingredients like barley indicate fine grinding of these types of ingredients may greatly improve their feeding value. A study was conducted with finishing pigs fed diets containing barley ground through a hammer mill equipped with either a 1/8, 3/16, or 1/4- inch screen or coarsely rolled (Table 4). Performance of pigs fed these diets was compared to those fed a diet containing milo ground through a 3/16- inch screen.

Pigs fed the barley diet ground through the 1/8- inch screen had similar average daily gain and feed efficiency compared to pigs fed the milo diet. Daily gain and feed efficiency became poorer as particle size of the barley diet increased. These data indicate grinding of fibrous feed ingredients to approximately 700 microns improves their feeding value and may make them more attractive as substitutes for corn and milo.

Because of its high protein content and propensity to become floury, wheat present some unique processing problems. If ground too fine, wheat can reduce feed intake. Recommendations for optimum particle size for wheat use in swine diets should be coarser than corn or milo, between 800 and 900 microns. Roller mills with a differential drive produce a uniform particle size and less fines and may be suited for processing wheat in swine diets.

Particle size data also may be confounded by the kernel size of the grain and the screen size or roller mill settings by which it is processed. For example, corn ground through a 3/16- inch screen will have a finer particle size than either milo or wheat because of its larger kernel size. Corn kernels must be fragmented before they can pass through a 3/16- inch screen opening; however, milo or wheat may fall through the opening intact because of their smaller kernel size.

It is difficult to make a specific recommendation for one screen for each type of grain, however, screen size should be adjusted to produce a mean particle size of 700 microns. As a rule of thumb, if there are whole kernels in your feed, it is probably not ground fine enough, and you may be losing 5 to 8 percent in feed efficiency.

Pelleted or Meal?

Pelleting adds cost to a batch of commercially processed feed. There are potential economic benefits though, shown by a large number of research studies over many years. Nursery pigs typically show an increased feed efficiency of 5 to 15 percent with pelleted rations compared to meal. Less advantage is seen in finisher studies, with 5 percent improvement in feed efficiency typical compared to meal diets. However, poor pellet quality usually wipes out any gains. You can tell poor quality pellets by large quantities of fines along with the pellets in the bin or feeder. As little as 20 to 25 percent fines can significantly reduce the benefits of pelleting in starter rations.

Pelleting appears to improve the nutritional value of high-fiber feed ingredients to a greater extent than that of low-fiber ingredients. This may be a result of increasing the bulk density of the feed. However, as energy costs increase, the economics of pelleting swine feeds may be questionable. The increased processing cost must be offset by the improved feed efficiency of pigs fed the pelleted diet.

Extrusion and Roasting.

Extrusion processing involves the application of heat, pressure, and (or) steam to an ingredient or diet. Extruders are sometimes used for on-farm processing of soybeans. If properly heated, this is an easy way to add fat to swine diets and utilize home grown soybeans. Recent research has shown that moist extruded soy protein concentrate or soybean meal as well as dry extruded whole soybeans are excellent protein sources for baby pigs. Because of volume, tonnage, and processing costs, extrusion of complete feeds is usually not economically justified based on performance of pigs fed extruded complete feeds. Extrusion processing increases the bulkiness of the diet, making it more difficult for the pig to consume enough feed to meet its nutrient requirements. Roasting can also be used to process home-grown soybeans. This can also be an alternative method for adding fat to swine diets. However, roasting temperature and times must be checked to ensure adequate processing. The added cost of the extruded, or roasted products must be the ultimate consideration in determining the feasibility of their use in swine diets.

Mixing.

Mixing is one of the most critical operations in feed manufacturing. Uniformity in the diet improves animal performance and limits the need for putting in extra nutrients just to be on the "safe side." To

check mixing uniformity, take 10 random samples from a load of feed and have them analyzed for protein and lysine and perhaps calcium and phosphorus.

Research work has shown a significant advantage of longer batch mixing time with nursery pigs fed a meal ration. However, with finishing pigs much less advantage has been shown. Our recommendation would be to err on the side of longer mixing time, especially in nursery diets, because the cost of additional mixing is low compared to the increased performance. There is also less potential for non-uniformity of micro-nutrients and other additives.

Use of pre-mixer will reduce both this potential and the required large batch mixing time. Don't overfill the mixer; over filling increases the time required for adequate mixing, and may make it impossible to make a uniform batch.

The sequence in which feed ingredients are added to a mixer may influence mixing efficiency and feed uniformity. Ingredients should be added in the following order: (1) half of the grain; (2) protein sources, vitamins, minerals, and feed additives; (3) the remainder of the grain.

Table 1. Effect of Particle Size of Corn and Sorghum Based Diets on Starter Pig Performance[a]

Grain	Mill Type	Mean particle size diameter (microns)	Average daily gain (lb)	Daily feed intake[b] (lb)	Feed/ gain[b]
Corn	Hammer	624	1.00	1.72	1.70
	mill	877	.99	1.77	1.78
	Roller	822	1.02	1.85	1.81
	mill	1,147	1.04	2.00	1.92
Sorghum	Hammer	539	.96	1.72	1.78
	mill	722	1.00	1.79	1.79
	Roller	885	1.00	1.91	1.92
	mill	1,217	.94	1.82	1.94

[a]Ohh et al., 1983. Values represent means from 192 weanling pigs initially 15 to 18 pounds with a final weight of approximately 512 pounds.
[b]Difference between hammer mill and roller mill ($P<.05$).

Table 2. Effect of Particle Size of Corn and Sorghum on Apparent Digestibilities[a]

Particle size (microns)	Digestibility, %			
	Dry Matter	Protein	Energy	Feed/gain
<700	86.1	82.9	85.8	1.74
700 to 1,000	84.9	80.5	84.4	1.84
>700	83.7	79.1	82.6	1.92

[a]adapted from Ohh et al., 1983.

Table 3. Effect of Diet Particle Size on Growth Performance of Starter Pigs[a]

Item	Particle Size, microns			
	900	700	500	300
ADG, lb	.84	.80	.85	.78
ADFI, lb[b]	1.29	1.21	1.23	1.19
F/G[c]	1.55	1.52	1.46	1.53
Production rate,t/h	4.06	2.84	1.63	.85

[a]adapted from Healy et al., 1994. Data represent means of pigs fed either corn and hard or soft endosperm milo ground to the respective particle sizes.
[b]Linear effect of particle size (P <.08).
[c]Quadratic effect of decreasing particle size (P <.01).

Table 4. Effect of Barley Particle Size in Finishing Diets[a]

Grain:	Milo	Barley	Barley	Barley	Barley
Screen Size, inches:	3/16	1/8	3/16	1/4	Rolled
Particle Size microns:	698	714	902	1,146	2,200
Average daily gain, lb	2.05[b]	1.96[b]	1.80[c]	1.78[c]	1.74[c]
Average daily feed intake,lb	6.93[b]	6.47[c]	6.20[c]	6.49[c]	6.49[c]
Feed efficiency	3.39[b]	3.32[b]	3.58[c]	3.65[c]	3.72[c]

[a]Goodband, et al., 1987.
[bc]Means on the same row with different subscripts differ (P <.02).

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Balancing Swine Diets for Profitability

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Swine producers have enjoyed relatively inexpensive feed costs for quite a while. However, recent $4 corn has united producers behind a common survival goal; increase feed efficiency and lower feed cost. Taking a close look at swine diets is crucial when facing high feed costs. Make sure you are not overfeeding amino acids, trace minerals, vitamins and phosphorus. Total phosphorus can be reduced dramatically by 0.2-0.3% once terminal market pigs reach 210 lb. three to four weeks before slaughter. If phosphorus is reduced, maintain a minimum level of salt in the diet and do not exceed three parts calcium to one part available phosphorus. The reduced phosphorus should be replaced with grain since phosphorus is up to three times more expensive than grain.

Rations are best balanced on an amino acid basis rather than a crude protein basis. This provides a more precise indication of ration adequacy. Lysine is the amino acid recognized as most limiting in swine rations. When formulating diets based on lysine utilizing intact protein sources, the requirement for lysine is precisely met. However, this creates a surplus in the other essential amino acids within the diet. Research at the University of Illinois suggest that the successful use of crystalline lysine results in formulating diets to the second limiting amino acid (tryptophan) and on an "ideal" protein basis. This results in a diet which, while lower in protein, will promote similar/improved pig performance due to more efficient utilization of nutrients.

Producers may want to consider lowering lysine levels for finishing from 0.7% to 0.6% at 230 lb. For each tenth of a percent of lysine removed, feed costs can be lowered by approximately $3/ton. Maintain lysine levels as close to the requirements as possible without overfeeding. When feed prices are low, lysine is often overfed to obtain carcass benefits. However, in light of current feed costs, feeding to lighter weights may result in similar carcass composition while increasing feed efficiency.

Anything that improves feed efficiency will be more economical in times of high feed costs. Replacing corn with 1% to 5% fat on an equal energy basis in the ration may also be a more inexpensive source of dietary energy. Since fat contains 2.25 times more energy than corn, producers may take advantage of fat anytime the cost of corn is greater than 2.25 times that of fat.

Utilizing high-oil corn is another option to achieve least cost swine rations without sacrificing performance. High-oil corn has a fat content of 6-8% (compared with 3-4% for regular corn) and lysine
levels of .28-.30% (compared with .25% for regular corn). Based on 22 University of Illinois

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swine diet formulations, an average savings of $7 to $9 per ton of feed can be realized by utilizing high-oil corn in grow-finish diets compared to diets containing regular corn plus 3% supplemental fat.

Another management tool that can help offset the high cost of feed is phase feeding. Phase feeding is a term to describe the feeding of several diets for a relatively short period of time in order to closely meet the pig's nutrient requirement. Many producers may consider adding a fifth or sixth phase into their feeding regime in an effort to more accurately meet the pigs nutrient requirements and reduce subsequent over- or under-feeding. When one diet is fed for a long period of time it is usually under the young pig's nutrient requirement and over fortified for the older pig. By adding another ration in the grower and finisher phases any over- or under-feeding is further minimized resulting in a more economical feeding program.

It's no secret, many producers realize that barrows and gilts have different lysine requirements during the finishing phase. At weights from 100 lb. to 200 lb. barrows require about .10% less lysine than gilts. From 200 to 260 lbs, the difference between barrows and gilts is not as great (.05% lysine). Financial rewards surely await those producers who implement split sex feeding. Economic benefits come through lowered feed costs by more precisely feeding the correct lysine levels to barrows and gilts, less sort loss at market, and more rapid turnover of pen space. Research by the Prairie Swine Center showed a $5 per pig advantage by split sex feeding. Approximately 60% of that advantage was attained by simply feeding gilts and barrows in different pens on the same ration because barrows can be sold sooner than gilts which allows pen space to turn over faster.

Feed represents 60 to 75 percent of the total cost of pork production, and this variable cost is one that managers can influence daily in their decisions regarding ingredients, feeds, and overall feed management. For each 10-cent increase in the cost of a bushel of corn, approximately 50-cents/cwt. is added to the cost of producing market hogs. Therefore, the feed cost per 100 lb. of gain is an important bottom line figure when considering alternative ingredients. In years past the most important growth traits that influenced rate of financial return were growth rate and feed conversion. Many producers are now faced with the reality that the carcass leanness of their pigs has a major influence on sale price and rate of financial return. Thus, optimization of carcass leanness must be considered along with growth rate and feed conversion when formulating and feeding swine diets.

One measure that combines growth with carcass merit is lean tissue growth rate. High lean gain pigs require more protein and lysine to realize their genetic potential than medium or low lean gain pigs. High lean gain pigs may be defined as having a rate of lean tissue deposition per day of .76 lbs or greater from 40 to 240 lb body weight. Medium lean gain pigs have a rate of lean gain of .6 to .75 lbs per day and low lean gain pigs gain less than .6 lbs of lean per day. Many producers know the average percent lean of their hogs, but, they may not know the average lean gain performance of their hogs. Lean gain performance can easily be calculated and many feed companies have programs that can help. Producers can also use information from a packer kill sheet for a group of pigs for which the starting date on feed and average initial weight has been recorded. This information can be applied to a National Pork Producers Council formula to estimate average lean gain per day for the group. The estimation formula is:

$$\frac{\left|\begin{array}{c}2.872 \square 0.469 \text{ x HCW, lb} \\ \square 18.47 \text{ x BF, in.} \\ \square 9.824 \text{ x loin depth, in.}\end{array}\right| \square \left[(0.418 \text{ x feeder pig wt., lb}) \square 3.65\right]}{\text{number days on feed}}$$

Several factors affect a pig's requirement for a specific nutrient. University of Illinois research has shown that the lysine level required to maximize lean gain is virtually the same as that required to maximize feed efficiency. Several factors affect a pig's requirement for a specific nutrient. These include breed, sex, genetics and energy concentration. Heat stress, disease and crowding **do not** increase the pig's requirement for protein or lysine expressed on a concentration (% of diet) basis. In fact, those stressors that decrease feed intake **decrease** the daily lysine requirement expressed in grams/day.

The goal for a nutrition program should be to provide each pig at the feeder with quality feed at a cost-effective price (this is not the same as a least cost per ton of feed diet system). As producers assume more responsibility for mixing their own feed, cost may be decreased. However, producers must supply additional facilities, labor, and quality control over a wide range of feed ingredients. This includes nutrient variability, vitamin and mineral stability, as well as adequate storage, processing, and mixing of diets.

Logical Steps in Formulating a Ration.

A. Identify animals to be fed by age, weight, function and specific conditions under which they are fed. Penning and feeding in uniform lots allows a producer to more accurately meet the pig's requirement.

B. Select a set of nutrient requirements most appropriate for the animals being fed. An authoritative source of information is Nutrient Requirements of Swine published by the National Academy of Sciences. Adoptions from this publication, mostly revised upwards, are widely used by universities and industry as a reference point for nutrition requirements.

C. Select suitable ingredients to help ensure that the ration is nutritionally balanced, palatable, safe, and economical. Guidelines for utilizing different feeds, example rations, and average analyses of selected ingredients can be found in the Pork Industry Handbook (PIH) fact sheet 7.

D Determine the necessary fixed amount of certain ingredients (mineral and vitamins) and mix grain(s) relative to protein supplement to provide the desired protein level.

Today most livestock rations including swine diets are balanced using computer programs. Computer ration balancing provides additional alternatives of ingredient substitution and reduces time and chances of error in hand calculation. Computers can handle the calculations of diet formulation efficiently, allowing you to examine rations in more detail and evaluate alternatives. The computer can rapidly select combinations of feeds that will meet nutrient requirements; and, when cost data are provided, it will select those that meet the requirements at the lowest cost. Computers can also be used to analyze your current feeding program by checking rations against accepted nutrient

allowances. Most of the computer software will balance diets for lysine first and phosphorous second since these two ingredients represent a high cost on a per pound of ingredient basis. Since feed cost represents a large portion of total swine production cost, a small savings can significantly reduce total cost.

The cost of ration balancing software ranges from $30 to $1000. A partial listing of programs and their vendors currently available include: Brill Feed Formulator (The Brill Corporation), The Consulting Nutritionist (Dalex Computer Systems), Professional Nutritionist (University of Minnesota/PNSwine), SPARTAN Swine Ration Evaluator (Michigan State University), Swine Diet Analysis and Relative Value (Iowa State University), TriLogic Feed Formulator (TriLogic Systems).

Building Environment: Effects on Feed Efficiency and Feed Consumption

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Many factors in the pig's immediate environment can affect the animal's growth and feed efficiency. Thermal environment, air quality, floor space allowance, and pig group management can all be manipulated to optimize feed efficiency.

Hot weather strategy. The pig's thermal environment, that is, the rate of body heat exchange to the surroundings, is crucial to growth performance. Every producer knows about a summer slump, when finishing hogs go off feed because the weather is hot. In one study of growing pigs, warm diurnal temperatures (daily cycling between 73° and 95° F) reduced the rate of gain 16.3% and increased feed intake 10.9% compared to pigs at a constant temperature of 68 F. Summer slumps can almost always be minimized with auxiliary cooling devices. A Kansas study of sprinkler cooling on finishing pigs in an open-front building showed no significant difference in feed efficiency with or without cooling, but the average daily gain was 1.80 pounds per day for the cooled pigs compared to 1.50 pounds per day for the uncooled control group. Since reproductive performance is closely tied to whole-herd feed efficiency, cooling the breeding herd (and especially the boar) pays off by increasing conception rate and number of pigs born per litter. At farrowing the sow is under stress in even the best room conditions; cooling the sow may increase the number of pigs born live, and number weaned. During lactation, the sow will eat better and get the pigs off to a quicker start if she is kept cool. This translates to higher weaning weights, less variation between littermates, and better sow condition for rebreeding.

Some cooling of hogs can be accomplished with air alone. There must be a temperature difference between the air and the pig's body core of about 10 degrees F or greater. That is, if the air temperature is above about 92 degrees there will be no cooling no matter how fast the air moves. An air speed of at least 2 mph (180 feet per minute) is recommended for auxiliary circulation fans, and 250-300 feet per minute is used as a design velocity in tunnel ventilated buildings. Pigs in crates can be zone cooled, using one air duct per animal, aimed at the head. Plan for at least 70 cubic feet per minute (cfm) of unconditioned air per sow in farrowing, 35 cfm per gestating sow, and 55 cfm per boar. One study of snout cooling on farrowing sows showed an increased feed consumption of 5 percent and a 5 percent increase in piglet average daily weight gain, compared to the uncooled control group. Water is one of the most effective ways to cool hogs. The simplest is to wet the skin of the pig and let air movement evaporate the water. Use circulation fans or tunnel ventilation where necessary. Use sprinklers, not fogger nozzles, because fog droplets will raise the relative humidity excessively. Turn on sprinklers when building temperature rises to 77° F, for growing/finishing pigs more than 100 pounds. For farrowing sows and heavier finishers, set the sprinkler valve thermostat to 75 F and for gestating sows and boars, set the thermostat to begin cooling at around 78 F. Evaporative cooling in conjunction with tunnel ventilation works well. In Illinois during many summer daylight hours there is a low enough relative humidity in the outside air to get substantial cooling (5-8 degrees F) of the ventilation air

through evaporation. However, the evaporative cooling may be more expensive to build than drip or sprinkling, and not be any more effective. A two-summer Oklahoma study of farrowing sows showed there was no significant difference between cooling the sow with drippers and cooling the entire room with an evaporator pad.

Cool weather strategy. Cool weather presents a completely different thermal environment challenge. Concrete and steel pens do not allow the pig as many options for keeping warm as do straw-bedded solid-floor pens. Therefore, the operator has to do a better job of managing the thermal environment in the building. An air speed of 30 feet per minute or less is recommended for nursery and growing pigs. If the air speed is 50 feet per minute, the wind chill effect on the pig is the same as reducing the room air temperature 1.5 degrees; at 100 feet per minute, there is about a 5-degree wind chill effect. Many confinement units have a couple of pens where one can measure air speeds at least 100 feet per minute in winter. Drafts lower feed efficiency through extra stress, extra feed energy requirement, and more health problems.

Air quality. Air quality can impact feed efficiency. High ammonia (probably greater than 15 ppm) in the pig environment has been shown to reduce the pigs' ability to clear pathogens from the lungs. Ammonia acts as a low-level stressor, robbing pigs of energy needed for growth. Keep room air velocities low in cool weather, because high air velocity picks up more ammonia from the manure pit or gutter surface. Farrowing and nursery rooms have the highest ammonia potential because the stored manure temperatures are highest in those. In partly slatted finishing buildings, keep the floors clean as possible, so that the pigs are not lying in wet manure. Ammonia tends to be highest in scraper-equipped rooms, followed by deep pit rooms, and lowest in gravity drain and pit recharge systems. Dust can stress the respiratory system, by carrying adsorbed gases deep into the lungs. Cut dust by regular thorough sanitation, adding fat or oil to the feed, keeping feed spout delivery points low in the feeder, and by careful regulation of the ventilating system in cool weather. High humidity is usually a problem in cold weather only, but high relative humidity tends to promote passage of airborne pathogens from pig to pig. This is because the aerosolized water droplets' pigs sneeze and cough into the air, carrying germs, do not dessicate very fast in humid air. The germs hitchhike on the droplets to the next pig and infect it. Control relative humidity by adjusting ventilation control settings, especially the air inlets.

Pig group management. One of the major benefits of all-in/all-out housing is the opportunity to completely sanitize the pens between pig groups. Feed efficiency almost always increases when the pathogen load on the animal is less, that is, when there is less germ-containing dirt ingested and inhaled by the pig. Clean regularly and thoroughly. Your first priority should be a good mechanical cleaning, and the second priority to disinfect. A Purdue University study showed, for smaller "low-tech" units, a change to all-in/all-out production brought a benefit of $1.79 per head, mostly due to improved feed efficiency and reduced time to market. Adopting segregated early weaning (SEW) plus all-in/all-out production had an impact of $11.59 per head sold in the operation. In any facility, there is an optimum amount of space per growing animal; crowding below that space allowance reduces feed efficiency. In times of high feed cost, you can afford to allow more space per pig and increase efficiency.

Conclusion. Many building environment changes are fairly easy to implement and can significantly improve herd feed efficiency.

"Fine Tune" Management to Reduce Swine Feed Costs

by
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When feed ingredient costs are high, swine producers must fine tune management practices to remain competitive in the 90's. Feed wastage can be a critical factor in the profitability of the swine enterprise. Estimates of typical feed waste range from 3-6% with some operations approaching a 10% loss. A mere 1% of wasted feed may amount to more than 1 ton of feed wasted per 100 sows per year.

Feeder Design: University of Illinois research in the late 80's indicated that feeder design can greatly affect feed wastage. The design not only affected feed left behind or wasted but the actual way the pig ate. The comfort and ease of access were important to the anxiety and injury level of the pig which influenced non wasteful eating habits. This research brought about the development of an "ideal" sow feeder that encouraged comfortable, noninjurious, non wasteful eating. The feeder included the following features: 1) Allowed individual approach to the feeder. 2) Feed delivery mechanism slowed the sow down as she ate thus reducing stress 3) The design allowed the sow to swallow with her mouth above or in the feeder. 4) No blind corners (easy access to the feed) 5) Free of protruding bolts, sharp edges and allowed clearance for the head and neck. Based on these findings feed wastage was reduced to 0.2% on the average. With grower and finishing feeders space was the greatest limiting factor, with adjustability and durability important areas of consideration. The greatest areas of concern were insufficient depth, height or angle of head clearance, front trough lips that were too high, or feeding spaces that were too narrow. Access to feed depends on size of the hog's head, size of the feeder opening and depth to the feeder bottom. Moisture wicking can reduce feed flow and quality in some designs. Fenceline feeders should give pigs sufficient space to stand and carry out normal eating actions. If pigs are uncomfortable, they will crowd other pigs and fighting may occur. Wastage in fence line feeders studied in the 80's ranged from two to 7%. Round feeders have the potential to give hogs better access to the trough. They have more shoulder room by design. The number of pigs that can use a round feeder depends on its size and placement in the pen. When the feeder is placed to close to dividers, that section of the feeder is more prone to being fouled. Circular feeder wastage ranged from two to 7%.

Feeder Adjustment: Feeder flow rate should be checked daily if possible and twice per week at minimum. Low flow rate may cause pigs to fight, reduce consumption and reduce rate of gain. Some pigs may just give up and not compete for feed. Heavy flow rates on the other hand become a costly waste. Fines tend to build up, moisture collects, and excess feed deteriorates in quality.

[1]*Contributing to this paper was: Gilbert Hollis and Mike Ellis - Department of Animal Sciences, University of Illinois, Ted Funk, Department of Agricultural Engineering, Bill Campbell - Farm Systems Educator - Springfield Extension Center and Dan Jennings - Animal Systems Educator Dekalb Extension Center.*

Some feeders have limited adjustment ranges. If you can see 40 to 60% of the feeder bottom, that setting should result in the highest feed quality and palatability, resulting in efficient feed conversion. This adjustment should improve rate of gain, compared to limited feed or too much feed in the feeder bottom. Less time and labor are needed at this setting. Don't restrict flow too much. Low consumption can be more expensive than a moderate waste.

Pig Density: Overcrowding can cause a number of management concerns. Inadequate ventilation or poor air quality may reduce feed intake and gains. Tail biting, fighting and other social vices may erupt and cause increased health risks. Information regarding pen space, feeder and waterer space may be found in the Midwest Plan Service - Swine Housing and Equipment Handbook (MWPS-8).

Water Usage: The goal of water use is to minimize water wastage without compromising pig production and/or welfare. Water is one of the most important nutrients required by swine. Environmental temperatures can increase water intake up to twice the norm. Nipple waterers provide cleaner water than cup or bowl types and nipples may waste less water. This is economically important because of the size and cost of manure storage and the cost of water and electricity. Check the flow rate and delivery pressure of each drinking device. High flow rates contribute to water waste and discourage pigs from drinking. Pressure on most lines should be 30-60 pounds per square inch (psi) while 20 psi is often suggested for small pigs.

Segregated Early Weaning: Weaning pigs early can minimize disease exposure from the sow. Colostrum should prevent the spread of disease for several days. The earlier pigs are weaned, the greater the odds that disease exposure will be eliminated. Providing the balanced, palatable, digestible ration is critical to the success of early weaning. A high density diet of 20-25% of milk and plasma protein is recommended to start early weaned pigs. Diets consisting of one to 1.5% lysine and 6-8 % fat are recommended.

Phase Feeding System: Nutritional requirements for early weaned pigs change rapidly during the early post weaning period. Phase feeding is beneficial in minimizing the adjustment to corn-soy diets. Phase I is a complex diet that is needed to achieve maximum feed intake and daily gain during week one of post-weaning. A phase I diet should only be fed for as short a time period as possible to reduce cost. Phase II is a less expensive diet designed to contain some palatability factors present in phase I and expose the pig to soy proteins. About one week of this diet is usually sufficient in most early weaning situations. Some researchers suggest that phase III diets contain whey or fishmeal. Very good results have been obtained with corn-soybean meal diet containing 1.1% lysine starting at three weeks post-weaning. This can be fed until pigs reach 45 pounds and are moved to a grower diet. At least two finisher diets should be used to reduce protein and amino acid content for heavyweight hogs.

Split Sex Feeding: Feeding barrows and gilts separately can pay off in three areas: performance, feed cost, and marketing. Gilts tend to perform better and will remain leaner to higher weights. Feed costs for barrows are usually lower since producers can sell barrows lighter and leaner. Split sex feeding keeps your groups more uniform. Carcass premiums often go up because of the uniformity of the load.

All-In/All-Out: Producers may gain from conversion to AIAO production. Building modifications and management practices may be necessary to adapt to AIAO technology. Production efficiencies for AIAO hogs suggest higher daily gains, better feed conversion and fewer days to market. Lower death loss and reduced medication costs are additional benefits expected from all-in all-out management.

The Effect of Genetics and Marketing Factors on Feed Efficiency[1]

by
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Consumers' demand for leaner pork has driven pork producers to emphasize the production of lean, muscular hogs. Nutrition and genetics are two of the major factors affecting the production of lean hogs. With the high cost of feed, it is critical that producers convert this as efficiently as possible. To maximize feed efficiency, producers must know feed intake, percent lean and the rate of lean growth of their hogs. Since many producers are marketing hogs at heavier weights, it is critical to know the additional cost and returns from these additional pounds. One method to approach this is to know your herds feed efficiency for each additional 20 pounds over 210 and then look at marginal feed/gain ratio and the marginal returns for these additional pounds.

GENETIC VARIATION

Even though improvement has been made in the composition of hogs, there are still wide variations in the U.S. swine population. The NPPC National Genetic Evaluation Program found genetic populations to vary as much as 5 percent in carcass lean. Discussion with packers has identified a variation from a high of 58 percent to a low of 43 percent, or 15 percent variation in percent lean in loads of hogs marketed.

Research has shown that it takes three to four times more energy to produce one pound of fat than one pound of lean since lean contains around 75 percent water compared to 10 percent for fat. Feed conversion was improved from 3.1 to 2.8 for the lean versus fat populations in the NPPC Genetic Test. Much greater differences would be found in feed efficiency from the diverse variation experienced by loads of hogs shipped to packers.

MEASURING LEAN GAIN GROWTH

Just knowing percent lean is not sufficient to optimize the efficient use of costly diets. A producer must also know the lean-gain-per-day value of his hogs. There can be a significant difference in rate of lean gain among pigs of similar lean composition. Research at Kentucky categorized high lean-gain-per-day of 0.8 or greater from 40 to 240 pounds of body weight. Medium lean gain pigs have an average lean-gain-per-day of 0.61 to 0.79 and low lean gain pigs have 0.6 pounds or less in lean-gain-per-day.

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[1]*Contributing to this article was: Dr. Tom Carr, Extension Meat Specialist, Dr. Mike Ellis, Pork Professor, and Leif Thompson, Extension Reproduction Specialist, University of Illinois Department of Animal Sciences; Dr. Al Mueller, Professor Emeritus, Agricultural Economics, University of Illinois Department of Agricultural and Consumer Economics.*

The accompanying figure is an example of the method of measuring "Lean-Gain-Per- Day" in your herd. This is relatively simple by monitoring a few pens of pigs through the growing and finishing barn and collecting only four different items of information from your facility and the packer kill sheet. The example depicts a pen of hogs that obtained 0.67 pounds of lean-gain-per-day which would fall into the medium lean gain ability. If your pigs fall into this category, then they should not be fed a diet designed for either high or low lean gain pigs. The extra nutrients and cost would be lost on such pigs.

MEASURING LEAN GAIN/DAY

Data Needed & Example:

Start Wt. & Lbs. Lean
(40#=13.1; 50#=17.2; 60#=21.4)
Days on Test..... 120
Ave. Carcass Wt. 180
Percent Lean..... 52

Calculations:

1. Carcass Wt. x % Lean = Lbs Carcass Lean
   180 x 52 = 93.6
2. Starting Wt. = Lbs. feeder pig lean
   40 = 13.1
3. Lbs. Carcass Lean - Lbs Feeder Lean = Lean Gain
   93.6 - 13.1 = 80.5
4. Lean Gain - Days on Test = Lean Gain/Day
   80.5 - 120 = 0.67 Lean Gain

FEEDING FOR LEAN GAIN

Targeting feeding programs to maximize lean gain will, in the majority of situations, also maximize feed efficiency and result in the production of leaner carcasses. Obviously, animals with higher lean gain growth are depositing higher levels of body protein and will require higher density protein and amino acid supply. The principal objective of nutritional programs that target maximum lean gain is to provide pigs with an adequate supply of amino acids for protein synthesis. Both under and over supply of protein is to be avoided. Diets that are inadequate in protein will reduce swine performance and increase costs, and oversupply of protein is expensive, increases nitrogen levels in the excreta, and can also reduce animal performance levels. The two major factors that will dictate the feeding program to maximize lean gain are lean growth potential and feed intake levels. The lean gain dictates the pig's requirements for protein and amino acids while the feed intake sets the level of these ingredients in the ration. We need information on both these components to optimize feeding strategies.

An example of how feed intake level and lean growth rates interact to determine the optimum feeding program can be seen by comparing the two sexes. Castrates generally have similar daily lean growth rates but higher intake levels than gilts. Therefore, the amount of protein required by the two

sexes on a daily basis would be similar, however, because the castrate eats more than the gilt, the optimum diet for a castrate would have a lower protein percentage than for a gilt. The optimum diet for specific genetic lines will also vary depending on their lean growth potential and appetite level. There is, however, little published information on these factors for the range of genetic lines used in the industry. In addition, the environment in which the pigs are reared can have a major impact on feed intake and lean growth and these are, therefore, likely to be specific to each unit and ideally should be measured or estimated under the conditions where the diets will be fed. A simple procedure to estimate lean growth rate has been outlined above. However, measuring feed intake under commercial conditions is no easy task and requires significant effort and, in practice, published values for the genotype and sex in questions are often assumed.

Recommendations for diets of different lean growth potential are available from the University of Illinois Cooperative Extension Service (ask for University of Illinois, Department of Animal Sciences Nutrition Group "Swine Diet Recommendations." These are based on published estimates for average feed intake levels which may well differ from those achieved in the barn. If this variation results from inherent differences in appetite between genetic lines or because of changes in the energy density of the diet, then this will not change the daily requirements for protein but will alter the protein and amino acid concentration needed to meet these requirements.

However, if a feed intake is depressed because of stress caused by factors such as crowding, heat, or disease then it is possible that these stressors will also depress a lean growth rate and reduce daily requirements for protein. The dietary protein percentage needed to meet these lower requirements will depend on the relative reduction in feed intake and lean growth. The best advice is to get accurate estimates of lean growth rates and feed intakes under the conditions on the farm in question and use these as a basis for formulating diets. If this is not possible, then published values can be used. If, however, performance levels on the commercial operation vary from these published values, as they often do, then this can lead to wrong diets being fed and reduced performance levels and increased costs.

WHAT WEIGHTS TO MARKET HOGS?

Choosing the ideal market weight is a critical factor to consider during high feed cost and narrow margins. The appropriate choice is associated with a number of factors specific to each farm such as genotype of the pigs, feed/gain ratio, capacity of finisher facility, and packer options. In general, as weight increases, feed and capital cost per pound of gain increases, while non-feed costs per pound sold decreases. From a genetic standpoint, low lean gain, early maturing pigs will reach peak growth and deposit more fat at a light weight (80 to 120 lbs.). While, the high lean gain, late maturing pig continues to increase the daily deposit of lean for a longer period and eventually reaches a higher peak at 170 to 180 pounds. Thus, the high lean gain pig will utilize feed more efficiently and the resulting carcass will contain more lean and less fat at heavier weights. Knowing the feed efficiency from grower to market weight is important. But of greater significance is having a handle on feed efficiency for each 20 lbs over and above 210 (ie, 210-230, 230-250, 250-270 lbs.)

One of the main decisions as to what weight to market hogs is driven by the "marginal feed/gain (F/G) ratio and the marginal return" for each additional 20 lbs. of weight added to the hog. With the

high cost of feed many pork producers are asking the following question, "What is the return for each 20 lb. gain increment from 210-230 lbs. and from 230-250 lbs. market weight?" The typical feed/gain ratio from 210-230 averages 4.1 to 1.0, and from 230-250 range, the F/G is 4.26 to 1.0. Selling hogs at 230 instead of 250 lbs. would save 87 lbs. of feed, or about 1.25 bushels of corn per head marketed. If you really cut back market weight from 250 to 210 lbs., you can save 2.4 bushels of corn per head. If one is only interested in saving sufficient corn to make it through to the next crop, then feeding to lighter weights might be the thing to do.

However, from an economic standpoint the individual pork producers must look at the added cost versus income for shipping at 250 lbs. or dropping back to 230 or 210 lbs. At $5.00 a bushel for corn, the cost per lb. of feed is 11 cents for feed cost of $9.02 for 20 lbs. of added gain for sale. Provided there is no discount for 230 lb. hogs, and the price of hogs are $60, you give up $12 in marginal revenue for a marginal feed cost of $9.02. Not necessarily an attractive trade off. If there is a discount for even lighter hogs (i.e. 210 lbs.), the advantage tips even further in favor of selling at normal market weights.

Thus, the trick for every pork producer is to feed your hogs to a minimum weight to prevent packer discounts for light hogs and then look at the "marginal cost/marginal return" by 20 lb. increments up to a weight where the packer will discount your hogs for weight and grade. If this marginal cost/marginal return is positive, then add the weight, while if it is negative then you will ship the hogs.

Staying current on the premiums and discounts for percent lean and carcass weights paid for your hogs by the various packers will be of utmost importance. Besides knowing your local packers buying criteria, you might want to obtain the "Eastern Cornbelt Lean Value Hog Trade" from the Illinois Department of Agriculture Division of Livestock and Grain Market News. If you are interested in obtaining this, call their office at 800/273-4763.

Pork producers must know the percent lean, lean-gain-per-day, and feed intake to optimize feeding strategies. Also, the ideal market weight to ship hogs will be determined by figuring marginal costs/marginal return.

On-Farm Feed Processing for Energy Efficiency and Optimum Swine Performance

by
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Introduction

The cost of feed is by far the largest single expense in swine production. Even small improvements in feed efficiency and reductions of feed wastage can easily result in large monetary returns in most swine operations.

Particle Size and Its Determination

The key to a good grind is getting the particle size right. The smaller the particle size, the more total surface area in any given amount of feed. More surface area means the enzymes in a pig's gut can more easily attack each feed particle, releasing its nutrients. The result is more efficient digestion. The greatest potential for fine grinding to improve feed efficiency will be for finishing pigs. However, fine grinding or rolling will improve feed efficiency regardless of age.[3] One of the disadvantages of fine grinding is the increased incidence of gastric ulcers. This is because finely ground feed is more fluid when mixed with the stomach secretions and the acids in the stomach have a greater chance of coming into contact with and irritating the esophageal region of the stomach. The frequency of ulceration increases when particle size gets below about 500 microns.

Determining particle size of feed should become a routine quality control measure on the farm. A program should include checking ground grain or one complete diet (grower, finisher, gestation, or lactation) at least twice a year and up to every 60 to 90 days for large operations. Work with your commercial feed ingredients supplier, nutrition consultant, or Extension animal sciences specialist for information regarding where to send the samples for sieve testing.

For finisher diets, Kansas State University proposes the following equation to estimate the economic consequences of changing particle size[3]:

$$\frac{F}{G} = Analyzed\ Particle\ Size\ x\ 0.0004152\ +\ 3.066$$

As an example, the projected feed/gain for 700 micron feed would be 3.36 based on Equation 1. If particle size increased to 1,100 microns, the projected feed efficiency would be 3.52 or an increase of about 5 percent. While the above equation also indicates that a decrease in particle size beyond 700 microns would continue to improve feed efficiency, the previous discussion indicates that there are ample reasons to keep particle size around 600-800 microns for swine diets.

One might ask whether particle size in that 1,100 micron range would not be easy to notice and correct, without sending a sample to a lab. Analysis of more than 2,500 feed samples over a six-year period at Kansas State University indicated that 74 percent of the samples had average particle sizes over 800 microns, and 33.7 percent were over 1,000 microns. Therefore, we might safely conclude that particle size is not that easy to "*eyeball*" and should indeed be checked by standard sieve testing in the laboratory.

Mills

Almost all grain ground for swine feed is processed through either a hammer mill or a roller mill. Feed processing equipment dealers often extol the virtues of the roller mill over the hammer mill or vice versa. Here are some comparisons of the two types of mills.

Particle Characteristics

Shape. Hammer mills are well suited to grinding a wide range of materials, from friable grains and soybean meal to fibrous ingredients such as oats and alfalfa. In addition, hammer mills are relatively simple machines to operate and maintain. Hammer milled particles tend to be more spherical and smooth. Rolled particles will be more elongated and flake-like with a rough texture and rough edges.

Coefficient of variation. Hammer milled grain tends to have more fines and an overall wider variation of particle size than roller milled grain. A properly-maintained and adjusted roller mill can hold a much tighter range of particle size than a hammer mill.

Implications of particle shape. There is some evidence that roller milled grain has slightly higher digestibility than hammer milled grain. This is probably because of the rough-edged texture of the roller milled particles compared to the more smooth-edged particles from the hammer mill. Rough edges present more surface area for digestive processes to proceed. However, the differences are very slight, and are apparently only significant in finisher diets compared to starter and lactation diets. Also, the bulk density of rolled grain is somewhat less than hammer milled grain, because the smooth-edged hammer milled particle packs tighter than the rough, elongated roller milled grain. Therefore, if a change of mill types is made, you may have to adjust other processes for a change in bulk density of ground grain. Hammer milled grain, if a small particle size is used, tends to bridge more than rolled grain. Also there is more dust in the feed.

Roller mills can handle wheat and grain sorghum more easily, with a more uniform particle size, than hammer mills.

There is some evidence that roller mill ground grain does not mix with vitamins, drugs and minerals as well as hammer milled grain. This is likely due to the shape of the particle.[1]

There is evidence that roller milled grain increases the power requirements for mixing operations compared to hammer milled grain. This is likely due to the flow characteristics of the cubic shape in rolled grains.[1]

Life-Cycle Cost

Capital cost. The initial cost of a farm-size stationary hammer mill setup is usually somewhat less than a roller mill. The larger sizes of mills show less installed-cost difference because of the increased amount of accessory equipment needed for hammer mills compared to roller mills.

Maintenance cost. Hammer mills need more frequent maintenance than roller mills, but the maintenance items are quicker and each costs less than roll recorrugation.

Energy cost. One source of mills for feed plants states that roller mills typically show 15-40 percent higher grinding energy efficiency than hammer mills. However, that source also states that the efficiency difference decreases as particle size decreases. Grinding finer than 700 microns with a hammer mill greatly increases the energy cost and reduces the rate of grinding. A Kansas State University study showed a decrease of **43 percent in feed production rate** (tons ground per hour) by decreasing particle size from 700 to 500 microns.[3]

Operation and maintenance: Hammer units. For best particle size control, keep the hammers and screen sharp. When the edges of the hammers get rounded and smooth, turn them or replace them if they have been turned once. The condition of the screen can have a big effect on energy consumption, mill throughput and particle size distribution. When the holes in the screen get worn around the edges, the grain tends to go around and around in the hammers instead of being broken up at the screen surface and going through the screen holes. Also, if whole pieces of grain show up in the feed, it is often because there is a hole in the screen. Usually this means you have to replace the screen. You should take a look inside the hammer mill about every two weeks, or more often if you process feed more than six hours a day.

Operation and maintenance: Roller mills. Most farm-scale roller mills have a single pair of rolls. Roller mills accomplish grain particle size reduction by compression, shearing and tearing. Compared to a hammer mill process, the roller mill heats the feed less, causes less moisture loss and makes less dust. Oats and barley can cause roller mills problems because of those grains' tough hulls. Production quality, capacity and efficiency decrease as finer grinds are expected from a single pair of rolls. This is why roller mills in feed plants often have two or more sets of rolls, the upper rolls spaced farther apart to accomplish the initial cracking of the grain and the lower set to finish the grind. The rolls in a pair are often operated at different speeds (called the "differential") and

sometimes the two rolls have different grooves per inch, for example, 10 grooves per inch on the fast roll and 12 grooves per inch on the slow roll. By using the differential rotating speed on the roller pair, there is more shearing action on the grain. Differential roll speed thus gives the roller mill some flexibility in handling different kinds of feedstocks.

When grinding corn with a roller mill, the operator should be aware of how changes in corn moisture affect the ground product. According to one large manufacturer, every 1 percent increase in corn moisture above 14 percent results in a 2 percent coarser product. Higher moisture also increases the grinding energy requirement.[5]

When the corrugations on rolls wear, they are less able to grind grain. The result is larger particles, even whole grains of wheat or grain sorghum, ending up in the finished feed. When enough wear occurs on rollers, they need to be taken out and sent off to be recorrugated. The recorrugation process grinds away some of the roller metal, thus reducing its diameter. There is a limit to the number of recorrugations that can be done before the roller is ground down too much to be reused. Most on-farm roller mills should probably be recorrugated at least every two years, depending on how much feed is ground and how much foreign material (soil and rocks) is in the grain. Usually a set of rolls is good for up to about six recorrugations before you have to throw them away and get a new set.

It is essential that the rolls on the roller mill be set exactly parallel. If rolls are closer together on one end than the other, it will be impossible to obtain the desired control of particle size. The ground product will be more coarse on one end of the rolls than the other.

Portable Grinder/Mixer Performance

While larger swine operations are moving to either off-farm feed processing or stationary on-farm processing units, the portable grinder/mixer is still used on a significant number of Illinois farms. Studies of portable grinder/mixer performance provide some tips on how to get the best use from the equipment, as well as how to budget time and labor costs for such systems.

Kansas State University time-motion studies in 1994 of portable grain mixers showed that on the average it takes about 42 minutes to grind grain, batch the feed, mix and deliver it to the feeder. Figuring the total on-farm feed production costs, they included the items shown in Table 1.

Table 1. *Fixed and variable costs of portable grinder/mixer operation on 18 Kansas swine farms. Dollars per ton of feed processed. Kansas State University study, 1996.*[4]		
	tractor	grinder/mixer
depreciation	$0.33	$0.54
maintenance cost	$0.75	$0.75
interest	$1.19	$0.69
fuel	$0.77	---------
labor	$0.96 to $5.23, average $2.27	
total costs	$3.14 to $13.75, average $7.22	

Their results show that there is a wide variation in total costs among farms, but give some basis for the smaller operations to decide whether it costs less to process feed on the farm or buy complete processed feed from a supplier. A comparison of processing options must assume that either feed source--on farm processing or buying complete feed--can maintain the same feed quality, including particle size.

Mixer Tips

Mixer filling: do not overfill a vertical mixer; since part of the mixing process involves slinging the feed out the top of the vertical screw and distributing it across the top width of the mixing chamber, an overfilled mixer won't get proper mixing action and may never get a complete mixing job done.

Mixing time: while some manufactures suggest 5 minutes mixing, it is probably better to allow 15 minutes after the last ingredient is added. Vertical-screw mixers are relatively slow compared to horizontal ribbon or paddle types, because in the vertical mixer only the material inside the vertical tube (about 15-20 percent of the total volume) is being handled by the mixing screw at any one time. To get a well-mixed batch, it is important that the operator does not rush the mixing process.

Wear: wear on the screw of a vertical mixer lengthens the time required to get a good mix. The auger intake at the bottom needs to be sharp and squared-off (like an auger drill bit). A worn mixing element can easily increase mixing time 50 percent. On a vertical mixer, the screw should probably be replaced when wear exceeds 1/2 inch.[2]

Mixer testing: every mixer should be tested, first to be sure it does mix, then to find out how long it takes to mix completely. Mix a batch, take a series of samples, then get an indicator-ingredient analysis (such as sodium) on each sample from your feed laboratory to see how well the batch was really mixed.

Segregation: segregation, or separation of feed particles after it is mixed, is usually not a problem in a mixer due to long mixing time; the operator should err on the long side of mixing time rather than mixing for too short a time. However, conveying mixed feed and letting it drop can segregate it, with the larger particles rolling farther from the center of the pile. Segregation can be lessened by using oil or fat in the feed.

Summary

Energy efficiency and operation of on-farm feed processing needs to be balanced against the requirements of feeding performance and animal health. Either hammer mills or roller mills can do an acceptable job of processing grains, especially corn. Feed particle size is particularly important. A particle size of about 700 microns seems to be a reasonable target to get:

- good digestibility
- optimum feed/gain performance
- good digestive tract health
- respectable grinding throughput
- acceptable amount of fines and dust
- good grinding energy efficiency

Routine mill maintenance and parts replacement will enable the system operator to get control of particle size. Mixers need to be tested and maintained to achieve uniform feed. More mixing time, rather than less, should be the rule. Mixer performance will be significantly improved when worn parts are repaired or replaced.

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Determination of Pregnancy and Estimation of Litter Size before day 30 of gestation based on blood hormones

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Introduction

Profitable production of pork depends to a significant extent on the number of piglets born and raised by each gilt or sow introduced into the breeding herd. A sow that does not conceive or has a small litter will reduce potential profit. Determination of pregnancy by ultrasonic echo amplitude is quite accurate from about day 30 to day 55 but gives essentially no indication of potential litter size. Analysis by real time ultrasound later in gestation can give some indication of the potential litter size but is expensive, requires much time and a certain measure of skill. Each fetus produces hormones as early as day 15. These hormones can be detected in the sow's blood beginning about day 18. The concentration of the hormones rises very rapidly from day 18 to day 28 and then declines sharply. Each fetus adds to the hormone concentration so that the concentration is influenced not only by the day of gestation on which a blood sample is taken but also on the number of fetuses contributing to the concentration of the hormone. Estrone glucuronide (E_1 G) is the hormone that is present in the greatest concentration and is easiest to measure and is related to pregnancy and litter size. Several studies were conducted to understand the relationships between day of gestation, pregnancy and litter size

Procedures

Forty two gilts were mated on the first day of heat and blood samples were taken on day 20, day 22 and day 24. The gilts were killed at days 29 to 35 and fetuses were counted. Thirty one gilts were then classified into groups on the basis of the concentration of estrone glucuronide (E_1 G) and the mean number of fetuses determined in each group. Litter size was plotted against concentration of E_1 G in 11 gilts.

Results

Determination of pregnancy was 100% accurate. Each non-pregnant gilt had clearly lower concentrations of E_1 G than pregnant gilts. The classification of 31 pregnant gilts into groups based on concentration of E_1 G resulted in a progressive increase in litter size with each increase in the minimum concentration of E_1 G (Table 1). The concentration of E_1 G rose very rapidly from day 20 to day 27 (Figure 1). Because the change in E_1 G is very rapid from one day to the next, an incorrect determination of day of first heat would possibly cause an error in estimating litter size based on concentration of E_1 G. This points out dramatically the absolute necessity for accurate and frequent detection of heat and careful and complete records. Litter size was related to concentration of E_1 G in 11 gilts at day 24 (Figure 2).

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Conclusion

Pregnancy can be detected with certainty as early as day 20 after mating by measuring the concentration of E_1 G in blood of a gilt. The same measurement will also give an estimate of potential litter size.

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Chen, S.-W., Z.Y. Chen and P.J. Dziuk. 1995. Determination of pregnancy and estimation of litter size in gilts based on concentration of estrone glucuronide and estradiol glucuronide in plasma. Anim. Reprod. Sci. 40:99-106.

Table 1. Effective litter size when gilts were classified into groups on the basis of the concentration of E_1 G on day 20 or day 22 of gestation.

Concentration of E_1 G (pg/ml)	*Number of Litters in Group*	*Resulting Mean Litter Size*
Day 20		
<1300 to >3400	30	7.9
<1300	5	5.0
<1500	13	5.1
>1300	25	8.4
>1500	17	10.0
>3000	11	11.3
>3400	7	11.7
Day 22		
<2600	5	6.2
<3400	16	6.5
>2600	26	8.4
>3400	15	9.5
>3900	11	11.7
>4700	7	12.3

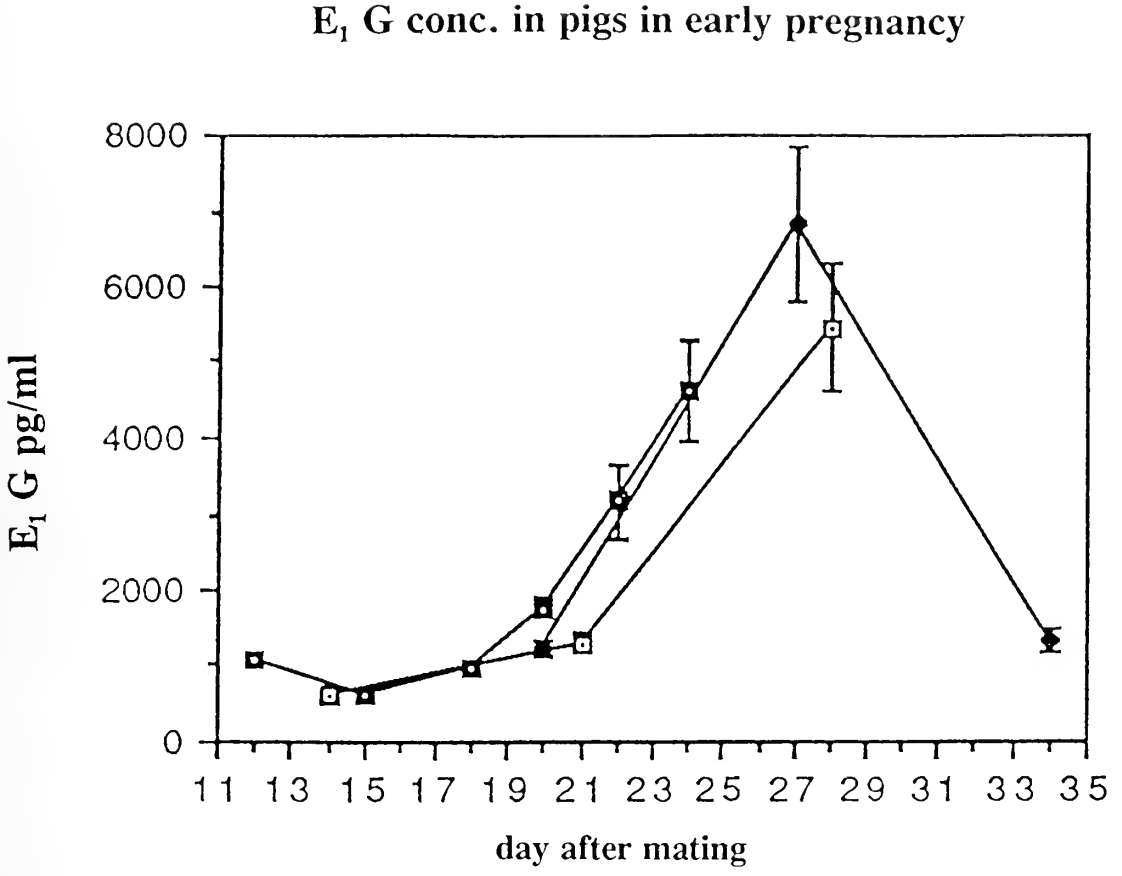

Figure 1. Profile of the concentration of estrone glucunoride (E_1 G) in relation to the first day of heat when mated.

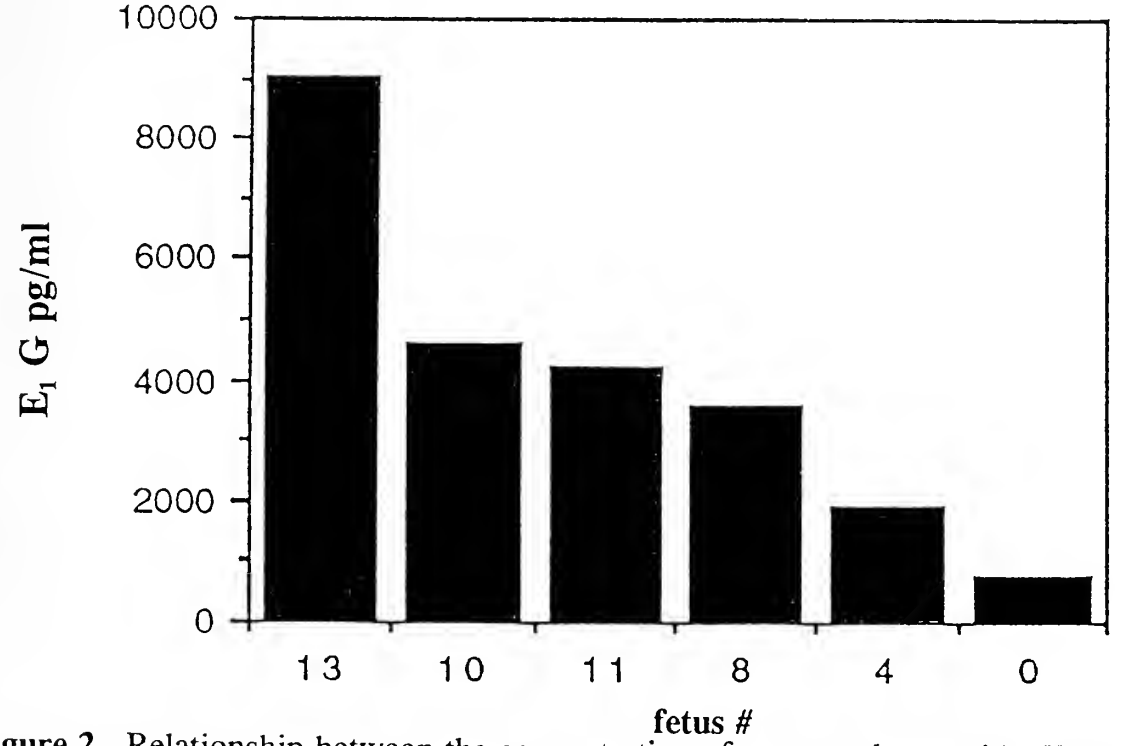

Figure 2. Relationship between the concentration of estrone glucunoride (E_1 G) on day 24 and litter size as determined at day 29 to day 35.

Examination of Ovulation Rate, Uterine and Fetal Interactions, and Reproductive Age in Chinese Meishan, Yorkshire, and Reciprocal Cross Gilts: Effects of Fetal and Maternal Genotypes

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Introduction

Investigation into the mechanisms of prolificacy of Meishan (Ms) pigs has lead to conclusions that differences among breeds involve several components of litter size. Components examined in Ms and occidental breeds have included follicular development, ovulation, time of ovulation, embryonic survival, and fetal survival .

Although many studies have examined Ms and Yorkshire (Y) females for embryonic survival (before 30 days of gestation), few laboratories have examined uterine and fetal interactions (after 30 days of gestation) in the Ms pig and their potential importance. We have reported that uterine and fetal interactions may have a role in the prolificacy of Ms females. Further, previous reports indicate that the number of fetuses does influence uterine length in occidental breeds of pigs. Evidence has indicated that ovulation rate of Ms and occidental pigs was similar at puberty and at early estrous cycles but diverged in favor of the Ms as they underwent more estrous cycles and later parities. Results from our laboratory indicated that ovulation rate was significantly higher for Ms females than for Y females at second parity but the reproductive age was not standardized.

The objectives were to determine the differences in ovulation rate, uterine length, space per fetus, fetal survival, and fetal development traits among cycle-matched (gilts bred at third estrus) Ms, Y, Ms x Y, and Y x Ms females at 50 days of gestation carrying 1/2 Ms and 1/2 Y fetuses. The objectives of Experiment 2 were to determine the differences in these traits for cycle-matched Ms and Y females at 50 days of gestation carrying purebred (Ms or Y) or crossbred (1/2 Ms and 1/2 Y) fetuses.

Materials and Methods

Two studies were designed to examine ovulation rate, uterine and fetal interactions, and reproductive age in Chinese Ms, Y and reciprocal cross gilts. Gilts were housed in adjacent pens in the same environmentally controlled building and fed the same diet. All breeds were moved from the nursery at 50 days of age (SD = 10) into the grower unit so they could adjust to a new environment and were moved at the same age (110 days) to the finishing unit.

In Experiment 1, daily estrous detection on 10 Ms, 10 Ms x Y, 10 Y x Ms, and 10 Y gilts began at 60, 100, 100, and 180 days of age (SD = 10), respectively, to determine age at first estrus. Gilts

represented six Ms, six Ms x Y, seven Y x Ms, and five Y families. Because sexual development can be delayed in prepubertal gilts when exposed to boars too early, Y and crossbred gilts were not exposed to boars at the same age as Ms gilts to avoid delayed attainment of puberty which would not be representative of either population. Daily boar exposure for 15 to 20 min continued until each gilt had three heats. At third estrus, Ms, Ms x Y, Y x Ms, and Y gilts were bred to Y, Ms x Y, Y x Ms, and Ms sires, respectively, at 12-h intervals each day they exhibited estrus beginning 12 h after the onset of estrus in Ms x Y, Y x Ms, and Y gilts and 24 h after the onset of estrus in Ms gilts. Meishan gilts have been reported to ovulate approximately 12 to 14 h later than Large White (LW) gilts relative to the onset of estrus. Each mating was to a different boar of the appropriate breed.

In Experiment 2, daily estrous detection on 10 Ms and 10 Y gilts began when gilts reached 60 and 180 days of age (SD = 10), respectively, to determine age at first puberty. Gilts represented 6 Ms and 5 Y families. At third estrus, Ms and Y gilts were bred to Ms and Y sires, respectively, at 12-h intervals each day they exhibited estrus beginning 12 h after the onset of estrus in Y gilts and 24 h after the onset of estrus in Ms gilts. Each mating was to a different boar of the appropriate breed. These gilts carrying purebred fetuses (Ms-P and Y-P) were compared to Ms and Y gilts carrying crossbred fetuses (Ms-X and Y-X) from Experiment 1.

In both studies, gilts were slaughtered at 51 days of gestation (SD = 2). Reproductive tracts (broad ligament removed) were examined 6 h after removal from the animal to standardize conditions for measurement. Ovulation rate was determined by dissecting and counting each CL. Uterine length was determined using a uterometer with measurements recorded in 1-cm increments. Fetuses were counted and spacing between fetuses was measured. Space per fetus was calculated as the sum of half the distance from neighboring fetuses. For fetuses at the tip of the uterine horn, the distance from the tip and half the distance from the neighboring fetus were summed. Head-tail orientation of fetuses was determined by palpation and sex of fetuses was recorded. Allantoic and amniotic fluid volumes from each feto-placental unit were measured separately in a 100-ml graduated cylinder. Fetal crown-rump length and weight were recorded.

Results and Discussion

In Experiment 1, crossbred gilts had a higher mean number of corpora lutea (CL; 17.3 for both crosses) and mean number of fetuses (14.7 for Y x Ms and 12.9 for Ms x Y) than either Y (12.5 CL and 10.9 fetuses) or Ms (14.2 CL and 9.2 fetuses; $P < .08$). Meishan and Y females had similar numbers of fetuses. Uterine lengths did not differ among groups ($P > .05$). Fetal weight, crown-rump length and amniotic fluid volume per fetus were highest for fetuses from Y females, intermediate for fetuses from Ms and Y x Ms females, and lowest for fetuses from Ms x Y females ($P < .05$). Fetuses in Ms gilts had more uterine space than the other groups ($P < .05$). Space per fetus was intermediate in Y and Ms x Y females and lower in Y x Ms females ($P < .05$). Volumes of allantoic fluid were greatest in Ms and intermediate for fetuses from reciprocal cross females and lowest for fetuses from Y gilts ($P < .10$).

In Experiment 2, breed of gilt effects were detected for number of ovulations ($P < .05$) but not number of fetuses ($P > .05$). The highest fetal survival occurred in Y-X females and the shortest uterine lengths were present in Ms-P females ($P < .05$). Fetuses in Ms-X and Y-P females occupied

the most uterine space, fetuses from Y-X females were intermediate, and fetuses from Ms-P females occupied the least uterine space ($P < .05$). Mean allantoic fluid volumes per fetus from Ms-X, Y-X, Ms-P, and Y-P were 177, 122, 99, and 69 ml, respectively ($P < .05$). Fetuses from Y-X females were the heaviest and had the most amniotic fluid followed by fetuses from Ms-X, Y-P, and Ms-P females, respectively. Fetuses from Ms-P gilts weighed less than fetuses from other groups ($P < .05$).

Reciprocal cross females (Ms x Y and Y x Ms) had higher ovulation rates and number of fetuses than Ms and Y females possibly due to hybrid vigor. However, length of the uterus was not influenced by their larger litter sizes suggesting that uterine capacity was not challenged at this reproductive age. It appears that there is a key point for Ms females where physiological and reproductive age must coincide to maintain improved prolificacy over domestic breeds of females. Therefore, the mechanism of fetal survival may be different in crossbred Ms females than in purebred Ms females. Finally, these data suggest the importance of ovulation rate, uterine and embryonic interactions, including uterine capacity, and reproductive age in the greater prolificacy of Ms females over occidental breeds of females.

Acknowledgements

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Mammary Gland Metabolism of Amino Acids in the Lactating Sow: An In Vitro Study

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Introduction

Economic demands on the pork producer will require that continued advances be made in optimizing farrowing rates, maximizing newborn pig survival, and increasing efficiency of preweaning pig growth and development. Success will be determined by the ability of the sow to produce sufficient milk to meet the needs of the rapidly growing litter. Genetic advances resulting in gains in litter size and milk production in sows have not always occurred with parallel advances in understanding the changing nutrient requirements by the pig. Amino acid requirements for milk production have come under particular scrutiny recently (Knabe et al. 1996; Richert et al. 1996). However, this process is being undertaken in a relative void of knowledge about how the sow mammary gland functions. To gain full value from efforts to revise amino acid requirement recommendations we must ultimately depend on an understanding of how the amino acids are utilized by the sow's mammary tissue.

Utilization of amino acids by a tissue can be considered in two stages, the uptake of amino acids by the tissue and their subsequent metabolism by the cells. This process is complicated by a number of potential metabolic fates of the amino acids once taken up by the cells. Incorporation into protein is a major fate of amino acids and synthesis of milk proteins is of primary concern in the lactating mammary gland. Several other fates of amino acids can also occur in the mammary cells resulting in cellular requirements which are in excess of those needed for milk protein synthesis. Essential amino acids (EAA) are absorbed in amounts adequate to account for their presence in milk protein, while non-essential amino acids (NEAA) generally show a deficit in uptake. Work with the ruminant mammary gland (Clark et al. 1978; Mepham 1982; Baumrucker 1985) indicates that several EAA (including lysine, phenylalanine, methionine, histidine and threonine) are transferred in amounts directly related to their amounts found in milk proteins, while others (including arginine and the branched-chain amino acids) are taken up by the gland in excess of their amounts found in milk proteins. The branched-chain amino acids (valine, leucine and isoleucine) are of particular interest because their fate in the tissue includes utilization as a potential energy source (often indicated by generation of carbon dioxide) and as a source of carbons and nitrogen for other metabolites such as NEAA, citrate, or fatty acids (Wohlt et al. 1977; Roets et al. 1979; Clark et al. 1978; Mepham 1982).

Limited information is available on the fate of amino acids in the lactating sow. Linzell and co-workers were the first to demonstrate an excess extraction of valine and arginine by the lactating sow mammary gland (Linzell et al. 1969). Only recently has this issue been reexamined. Investigations

of mammary arteriovenous (A-V) differences of amino acids and amino acid utilization confirm the importance of EAA for the lactating sow (Easter and Trottier 1996). In addition, these A-V difference studies indicate that the branched-chain amino acids are absorbed by the mammary gland of the lactating sow in significantly greater amounts than can be accounted for by the output of milk protein (Easter and Trottier 1996).

The requirement of the lactating sow for branched-chain amino acids apparently involves more than just synthesis of milk proteins. Recommendations for appropriate amino acid requirements for optimal milk production by lactating sows hinge on a better understanding of the utilization of these branched-chain amino acids. This paper summarizes an in vitro study of amino acid utilization by lactating sow mammary tissue. The objective was to characterize the utilization of valine, leucine and lysine by lactating sow mammary tissue using an in vitro tissue culture approach. Metabolism of valine and leucine were compared with that of lysine. Lysine was chosen because it has the highest transfer rate from arterial blood to milk protein of the EAA (Clark et al. 1978), its dietary requirement is highly correlated with milk yield in sows (Knabe et al. 1996), and it is often used as a reference standard in dietary and amino acid utilization studies (Baker 1995).

Experimental Approach

Lactating sows (day 21 of lactation) were obtained from the University of Illinois swine herd and slaughtered at the University of Illinois Meat Science Laboratory abattoir. Litters were removed immediately prior to slaughter. Mammary tissue was cultured in medium containing one of the three ^{14}C-labelled amino acids (lysine, leucine or valine), supplemented with glucose and acetate as substrates. Radioactive carbon dioxide generated during culture and metabolism of radiolabelled amino acids to fatty acids or glycerol were also estimated. Media and explants were also assayed for total protein synthesis and secretion by acid precipitation.

Results and Discussion

Utilization of valine, leucine and lysine was compared in the mammary tissue explant culture system (Table 1). Oxidation to carbon dioxide, metabolism to fatty acids and glycerol and incorporation into protein were determined. All three amino acids were converted to carbon dioxide, although to different degrees. The extent of oxidation of valine to carbon dioxide (16.7% of total estimated substrate conversion) was higher than reported for other species, although it is often difficult to make direct comparisons among the numerous approaches for determining the extent of this metabolic process. In mammary gland perfusion studies, about 6% of radioactivity of valine was recovered as carbon dioxide in the guinea-pig (Davis and Mepham 1976) and about 10% in the goat (Roets et al. 1979), although in the latter study the authors estimated that 30% of valine taken up by the mammary gland was oxidized to carbon dioxide. In a study of cow mammary tissue explants which used a tissue culture system similar to our's, recovery of radiolabelled carbon dioxide accounted for 1.4 % of total absorbed valine, or about 3.7% of metabolized valine (Wohlt et al. 1977).

Table 1. *Conversion of amino acids by lactating sow mammary tissue explants as percent of total substrate conversion*[1].

Amino Acid	Carbon Dioxide	Fatty Acid[2]	Glycerol[3]	Protein[4]
Valine	16.7%	0.9%	0.4%	82.0%
Leucine	11.2%	6.2%	2.8%	79.8%
Lysine	6.0%	3.5%	0.7%	90.2%

[1]Estimated from mean of 4 experiments.
[2]Chloroform:methanol extractable material.
[3]Radiolable in aqueous phase after organic extraction.
[4]Radiolabelled material in trichloroacetic acid precipitate.

Lactating sow mammary tissue oxidized about 11.2% of the metabolized leucine to carbon dioxide (Table 1). This is also higher than the level of carbon dioxide generated from leucine by cow mammary tissue explants which accounted for 5.1% of total absorbed leucine (Wohlt et al. 1977) and about 9.2% of metabolized leucine. Interestingly, 6.0% of metabolized lysine ended up in carbon dioxide, suggesting that not all lysine is incorporated into protein by the tissue.

Valine is a glucogenic amino acid and would not be expected to participate in synthesis of fatty acids, as indicated by the low conversion of radiolabelled valine to fatty acids (Table 1). Gluconeogenesis, while important in the liver, does not occur in the mammary gland. Valine was not converted to lactose in the perfused goat mammary gland (Roets et al. 1979). Leucine is a ketogenic amino acid and a small proportion of the metabolized radiolabelled leucine is found in the extracted fatty acid fraction (Table 1). The fatty acid fraction here would include other organic metabolites which would be generated from these amino acids such as ß-hydroxyisobutyrate from valine and isovalerate from leucine (Wohlt et al. 1977). A small amount of the lysine radiolable was found in the fatty acid fraction (Table 1). Lysine can also be ketogenic in tissues. Utilization of the three amino acids for glycerol was minimal (Table 1).

The major proportion of the utilization of these three amino acids was for protein synthesis (Table 1). Although primarily representing protein synthesis, this acid precipitable fraction would include other macromolecules such as nucleic acids. The 82% of metabolized valine found in the acid precipitable fraction was only slightly lower than the 88% found in cow mammary tissue explants (Wohlt et al. 1977) in a comparable fraction (acid precipitable plus cell debris). Because of the relatively high metabolism to fatty acids, leucine incorporation into protein was only 80% of total utilization. This compares well with the 82% incorporation of leucine into a similar fraction in cow mammary tissue explants (Wohlt et al. 1977). We did not account for participation of valine and leucine as substrates for conversion to other amino acids. However, this latter conversion was relatively minor in cow mammary tissue explant studies (Wohlt et al. 1977). Lysine was incorporated into protein at 90% of total metabolized radiolabelled amino acid (Table 1).

Total in vitro substrate conversion of valine and leucine relative to total substrate conversion of lysine was 122% and 114%, respectively. These numbers are interesting in comparison with dietary requirements for these amino acids in lactating sows. Recent studies suggest that current recommendations for lysine for lactating sows do not meet the demands of today's high-producing lactating sow (Knabe et al. 1996). Other studies indicate that a valine:lysine ration of at least 128% in the diet is required (Richert et al. 1996). In addition, other feeding studies found that feeding the leucine metabolite ß-hydorxy-ß-methyl butyrate increases milk fat percentage (Nissen et al 1994), suggesting that leucine metabolism normally may contribute to fat synthesis by the mammary gland. This is consistent with the high leucine:lysine uptake ratio found in amino acid uptake studies of sow mammary gland (Easter and Trottier 1996).

Conclusions

Results from this in vitro study suggest that a considerable proportion of metabolism of valine and leucine by lactating sow mammary tissue is not directly resulting in production of milk protein. Valine seems to be extensively oxidized to carbon dioxide, while leucine contributes to fat synthesis by the tissue. These results are consistent with findings by recent in vivo uptake studies and feeding studies aimed at establishing dietary requirements of the lactating sow. Dietary requirements for these amino acids should take into account that valine and leucine are utilized by the mammary tissue for more than milk protein synthesis. The finding that a limited proportion of lysine was also metabolized for uses other than protein synthesis should be understood when considering amino acid:lysine rations for lactating sows.

Some Remaining Questions

Several questions remain about amino acid utilization by mammary tissue in the lactating sow. These should be addressed in order to maximize the value of feeding trials aimed at reexamining amino acid requirements of high-producing lactating sows. Dietary amino acid ratios need to be balanced because dietary excesses of certain amino acids, especially lysine, can cause deficiencies in other amino acids (Baker 1995). At the same time, uptake studies in several species suggest that there is competition among amino acids for cellular uptake carrier systems (Baumrucker 1985). For example, lysine transport into rat mammary tissue is inhibited by both cationic and neutral amino acids, including leucine (Shennon et al 1994). It is not known whether other amino acids can spare the non-protein synthetic utilization of some amino acids once inside the cell. For example, the conversion of leucine to fatty acid by the tissue may be altered by changing the ratios of other ketogenic amino acids.

Our in vitro explant studies were done using mammary tissue from day 21 of lactation. Others have shown that the extraction rate for lysine from the blood increases as lactation progresses (Easter and Trottier 1996). We hypothesize that the utilization of amino acids by mammary tissue does not remain constant throughout lactation. Comparisons of amino acid utilization by mammary tissue from different phases of lactation are needed to extend our understanding of amino acid utilization by sow mammary tissue throughout lactation.

Estimates of amino acid requirements for lactating sows may account for increasing litter weight gain and increasing milk yield during lactation. However, they do not take into account the proportion of amino acid incorporated into mammary proteins in a rapidly growing tissue. Mammary growth during lactation has been demonstrated in several other species (Tucker 1987). Nearly a third of total mammary growth in the rabbit occurs during lactation (Lu and Anderson 1973) and the post-partum growth of the gland may equal that occurring during pregnancy in the rat (Tucker 1987). Nursing intensity is a major stimulator of mammary growth in the litter-bearing species (Tucker 1987). The extent of mammary growth in lactating sows needs to be determined.

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Effects of Fumonisins on Cardiovascular Function in Swine

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Introduction

Fumonisins (FB), are a group of naturally occurring mycotoxins produced by the fungus *Fusarium moniliforme*. These toxic metabolites of corn have been implicated in field cases of porcine pulmonary edema (PPE). The mechanism of fumonisin-induced pulmonary edema in swine is currently unknown; however, it may be related to altered sphingolipid biosynthesis. It was recently discovered that fumonisins are naturally occurring inhibitors of sphingosine (sphinganine) *N*-acyltransferase. This enzyme is a key component in the pathway for sphingolipid biosynthesis. We previously reported that this fumonisin-induced enzyme inhibition results in increased concentrations of free sphinganine and sphingosine in the serum and tissues of swine, as well as a depletion of complex sphingolipids. Sphingosine is an important intracellular second messenger that participates in receptor interaction and signal transduction through modulation of various calcium channels, protein kinases, and calmodulin-dependent enzymes.

More recent studies have shown that low concentrations of sphingosine inhibit the L-type calcium channels in the heart, thereby potentially reducing cardiac contractility. *In vitro* studies using frog atrial muscle tissue have demonstrated that fumonisin blocked L-type calcium channels and decreased atrial mechanical activity. It is therefore likely that a fumonisin-induced increase in sphingosine concentrations could produce various cardiovascular effects in pigs, thereby inducing the pulmonary edema seen in field cases of fumonisin toxicity.

Objectives

1. To examine the effects of fumonisins on the cardiovascular system of swine.
2. To determine if fumonisins decrease cardiac contractility in swine.

Results

In 2 separate studies, groups of pigs were fed fumonisins at a dose of either 0 or 20 mg hydrolyzed fumonisin B_1/kg/day for 7 days. On day 8, pigs were anesthetized and surgically fitted with arterial and/or pulmonary catheters. Cardiovascular measurements were obtained during anesthesia and 18 hours after recovery from anesthesia. Pigs fed fumonisins had significant decreases in maximal rate of change of left ventricular pressure (dP/dt_{max}), heart

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rate, cardiac output, and mean aortic pressure, a significant increase in mean pulmonary artery pressure and pulmonary vascular resistance, and no change in left ventricular end-diastolic pressure, pulmonary wedge pressure, ventricular relaxation rates, and central venous pressure. Additionally, there were no significant differences found in electrocardiograms from fumonisin-treated pigs.

Discussion

The major findings of these studies were that fumonisin decreases the cardiac contractility of pigs (reduced dP/dt_{max}) without effecting the rate of ventricular relaxation. Additionally we have demonstrated a reduction in heart rate, cardiac output, and mean aortic pressure, with a significant increase in pulmonary artery pressure. We also found that sphingosine and sphinganine concentrations are increased in the cardiac muscle of fumonisin-treated pigs as compared to controls.

These results indicate that field cases of fumonisin-induced pulmonary edema in swine are due to left-sided heart failure. We propose that the fumonisin-induced increase in tissue sphingosine concentrations inhibits the L-type calcium channels of cardiac cells, thereby decreasing calcium release and cardiac contractility. The increase in sphingosine also inhibits the calcium channels of cardiac pacemaker cells thereby decreasing heart rate. Pulmonary edema is likely to form as the contractile rate of the heart decreases mean arterial pressure below the level needed for the regulation of the cardiac circulation.

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